SPAWNING AND EARLY LIFE-HISTORY CHARACTERISTICS OF BULL TROUT IN A HEADWATER-LAKE ECOSYSTEM

by

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ABSTRACT

Bull trout *Salvelinus confluentus* are in decline throughout their native range. Interaction with nonnative species is considered to be one of the drivers of bull trout decline. Bull trout exhibit a variety of life-history strategies and lacustrine-adfluvial bull trout seem to be particularly susceptible to population decline when nonnative lake trout *S. namaycush* invade or are introduced into lakes where bull trout are the dominant salmonid. Quartz Lake in Glacier National Park, Montana, provided a unique opportunity to gather information on the spawning and early life-history characteristics of a bull trout population prior to anticipated declines in bull trout abundance due to lake trout invasion. The objectives of this study were (1) to characterize the spatial and temporal dynamics of bull trout spawning migrations and associate areas of high redd accumulation to abiotic factors, and (2) to quantify the influence of abiotic factors on the distribution of subadult bull trout in tributary streams of Quartz Lake. Stream surveys were conducted to quantify physical habitat characteristics in the study area, backpack electrofishing was used to sample subadult bull trout rearing in lake tributaries, and redd surveys were used to investigate the spatial and temporal trends in the accumulation of bull trout redds. Bull trout redds and subadult bull trout were found throughout the study area; however, bull trout spawning and rearing appeared to be concentrated in lower Quartz Creek. This area was low gradient, and there was a high percent of gravel and cobble substrates. Bull trout spawning began in late September, peaked in early October, and concluded in mid-October. These data provide important information on bull trout life-history in headwater lakes and provide biologists with baseline data that will be useful for assessing the effects of lake trout suppression efforts that began in 2009.

INTRODUCTION

The introduction of fishes into areas outside of their native ranges has occurred for thousands of years (Li and Moyle 1999). Many of these introductions have historically occurred with the intention of enhancing recreational fishing; however, a result of these introductions is often a reduction in native species biodiversity (Lodge 1993; Knapp et al. 2001) through predation and competition (Vander Zanden et al. 1999), and loss of genetic diversity (Ferguson 1990). For example, the abundance of yellow legged frog *Rana mucosa* is less where fish have been introduced compared to fishless water bodies (Knapp and Matthews 2000). Additionally, the introduction of rainbow trout *Oncorhynchus mykiss* into cutthroat trout *O. clarkii* habitat has been shown to reduce the genetic integrity of westslope cutthroat trout *O. c. lewisi* (Muhlfeld et al. 2009) and Yellowstone cutthroat trout *O. c. bouvieri* (Kruse et al. 2000) populations due to hybridization.

A substantial proportion of natural resource management is currently focused on restoration activities. However, information on ecological conditions prior to ecosystem perturbations is useful for managing ecological systems for the present and future (Landres et al. 1999). Therefore, effective restoration is aided by reference or baseline data to define restoration benchmarks, determine restoration-site potential, and evaluate restoration efforts (White and Walker 1997). Baseline data need to incorporate the composition, structure, dynamics, and spatial context of a species or ecosystem (White and Walker 1997). Furthermore, accurate baseline data for species at all life-history stages are important in restoration and recovery (Pauly 1995; White and Walker 1997), especially if the species is threatened or endangered. Site- or population-specific baseline data may be particularly useful for conservation and recovery efforts aimed at species that exhibit species-level variability in ecological characteristics, life-history strategies, or evolutionary histories.

One species that may benefit from site-specific or population-specific baseline data is the bull trout *Salvelinus confluentus*. Bull trout is a species of char endemic to western North America. The historic distribution of bull trout includes coldwater habitats in northern California and Nevada, east of the Continental Divide in Idaho, Montana, and a small portion of Wyoming, throughout the majority of Oregon and Washington, and north into British Columbia and Alberta (McPhail and Baxter 1996). Bull trout are also present in the foothills on the east side of the Continental Divide in northwest Montana.

Bull trout exhibit variability in ecological and life-history characteristics throughout their range. For example, both migratory (potamodromous and anadromous) and non-migratory (resident) life-history strategies have been documented, and potamodromous bull trout exhibit fluvial, fluvial-adfluvial, lacustrine-adfluvial, or allacustrine migration patterns (terminology follows Varley and Gresswell 1988; Northcote 1997). Variation in life-history strategies can arise from spatial, seasonal, and ontogenetic separation of optimal habitats for growth, survival, and reproduction (Northcote 1984).

Bull trout spawn in the autumn, and changes in river discharge, water temperature, and declining photoperiod coincide with bull trout spawning migrations (Fraley and Shepard 1989; Brenkman et al. 2001). However, spawning migrations by adfluvial bull trout may begin as early as April and can entail migratory distances > 250 km (Fraley and Shepard 1989). Bull trout redds are often constructed in areas of low stream gradient and abundant gravel substrate (Fraley and Shepard 1989).

Length-frequency data for subadult bull trout from the Flathead River Basin suggest that bull trout are approximately 50-70 mm at age 1, 100-120 mm at age 2, and 150-170 mm at age 3 (Pratt 1992). Migratory forms of subadult (i.e., sexually immature) bull trout emigrate from natal tributaries to larger rivers and lakes primarily at age 2 (Fraley and Shepard 1989; Pratt 1992); however, a large number of age-0 bull trout may emigrate in association with spring runoff and warming water temperatures in some systems (e.g., McPhail and Murray 1979; Downs et al. 2006). Subadult bull trout in natal tributaries are positively related to pool habitat (Saffel and Scarnecchia 1995), cover (Bonneau and Scarnecchia 1998), and areas of low gradient (Rich et al. 2003). Additionally, subadult bull trout are found to be negatively related to fine sediment (Dambacher and Jone 1997; Thurow 2006).

Although bull trout were historically widespread in western North America, this species was listed as threatened in the Columbia River drainage under the U.S. Endangered Species Act in 1998 following population declines throughout the historic range. Bull trout populations may be negatively affected by habitat alterations, such as fragmentation caused by dams, dewatering, and elevated temperatures (Nelson et al. 2002), and global climate change is predicted to result in broad-scale decreases in suitable habitat for bull trout (Rieman et al. 2007). However, nonnative species may negatively influence bull trout populations (Rieman and McIntyre 1995) even where anthropogenic habitat alterations have been limited (e.g., protected lands such as state and federal parks and wilderness preserves).

The introduction of lake trout *S. namaycush* into Flathead Lake, Montana, in 1905 (Spencer et al. 1991) poses a threat to lacustrine-adfluvial bull trout populations. For example, lake trout have been shown to negatively affect bull trout populations in as little as 20 to 30 years (Donald and Alger 1993; Fredenberg 2002; Martinez et al. 2009), and the ongoing spread of lake trout in the Flathead River drainage has resulted in colonization and establishment of lake trout in the majority of lakes on the west side of the Continental Divide in Glacier National Park, Montana. Furthermore, lacustrine-adfluvial bull trout occupying headwater lakes in Glacier National Park may exhibit life-history characteristics that differ from bull trout in larger systems. For example, redd survey data suggests that individuals from these lakes frequently migrate only a few kilometers upstream to reach the natal spawning grounds (Meeuwig and Guy 2007), spawning generally occurs over a short period of time, and postspawning adults return directly to the lake. Additionally, subadult bull trout may emigrate from natal rearing habitats at earlier ages than observed in larger lake-river systems because of the harsh summer and winter conditions found in high elevation systems in Glacier National Park (e.g., Meeuwig 2008). Therefore, site-specific baseline data may be necessary to document potentially novel life-history characteristics and to provide a benchmark for bull trout conservation and recovery efforts within Glacier National Park.

Bull trout research and monitoring in Glacier National Park has primarily focused on adult and sexually immature fish susceptible to sampling with gillnets in lacustrine environments (e.g., Fredenberg 2002; Dux 2005; Meeuwig 2008; Meeuwig et al. 2008; Meeuwig et al. *in press*). Consequently, data regarding spawning dynamics of lacustrine-adfluvial bull trout and life-history characteristics and habitat requirements of subadult bull trout in natal habitats are lacking, and baseline data for use in conservation and recovery planning are generally limited to historical accounts (e.g., Schultz 1941; Morton 1968).

Quartz Lake is currently a site of bull trout conservation priority in Glacier National Park. Prior to 2005, Quartz Lake, a natural headwater lake without road access, was the fourth largest lake in the Columbia River Basin without introduced salmonids (W. Fredenberg, USFWS, personal communication). Lake trout were first documented by anglers in Quartz Lake in July 2005. Gill-net surveys conducted during 2005 and 2006, and bull trout redd surveys conducted in 2004 through 2006 indicated that bull trout were still abundant in Quartz Lake and that the relative abundance of lake trout was low compared to other lake trout invaded systems in Glacier National Park (Meeuwig and Guy 2007; Meeuwig et al. 2008). Therefore, the lake provided an opportunity to gain information on a system of conservation concern prior to population level declines in bull trout that have been observed in other systems (e.g., Donald and Alger 1993; Fredenberg 2002). Additionally, an experimental lake trout suppression effort began in Quartz Lake during the autumn of 2009 (C. Downs, USNPS, personal communication); consequently, data gathered from the current study will be directly applicable to evaluate bull trout conservation efforts. Therefore, the objectives of this study were (1) to characterize the spatial and temporal dynamics of bull trout spawning migrations and associate areas of high redd accumulation to abiotic factors and (2) to quantify the influence of abiotic and biotic factors on the distribution of subadult bull trout in tributary streams to Quartz Lake.

METHODS

Study Area

The study system included portions of the drainage network upstream of Quartz Lake. Quartz Lake is located in the North Fork Flathead River drainage on the west side of the Continental Divide in Glacier National Park. Quartz Lake has a surface area of 352 ha, maximum length of 4.8 km, and maximum depth of about 83 m, and is situated in a glacially carved basin that is primarily fed by snow and glacial meltwater. Quartz Creek, the main tributary to the lake, flows about 7 km (stream length) from the outlet of Gyrfalcon Lake to Quartz Lake. Rainbow Creek drains Cerulean Lake and flows downstream about 2 km (stream length) from the outlet of Cerulean Lake before entering Quartz Creek approximately 1.3 km upstream from Quartz Lake. Data collection focused on Quartz Creek from the inlet of Quartz Lake upstream to a putative fish barrier and Rainbow Creek from its confluence with Quartz Creek upstream to the outlet of Cerulean Lake (hereafter referred to as the Quartz Lake drainage; Figure 1).

The Quartz Lake drainage was partitioned into three stream segments based on stream hydrology and stream order (Figure 1). Lower Quartz Creek included contiguous mainstem and side channel habitat between the inlet of Quartz Lake and the confluence of Quartz and Rainbow creeks. Upper Quartz Creek extended between the confluence of Quartz and Rainbow creeks and the putative fish barrier on Quartz Creek, and Rainbow Creek included contiguous mainstem and side channel habitat between the confluence of Quartz and Rainbow creeks and the outlet of Cerulean Lake (Figure 1). All sampling occurred during the summer and autumn of 2008.

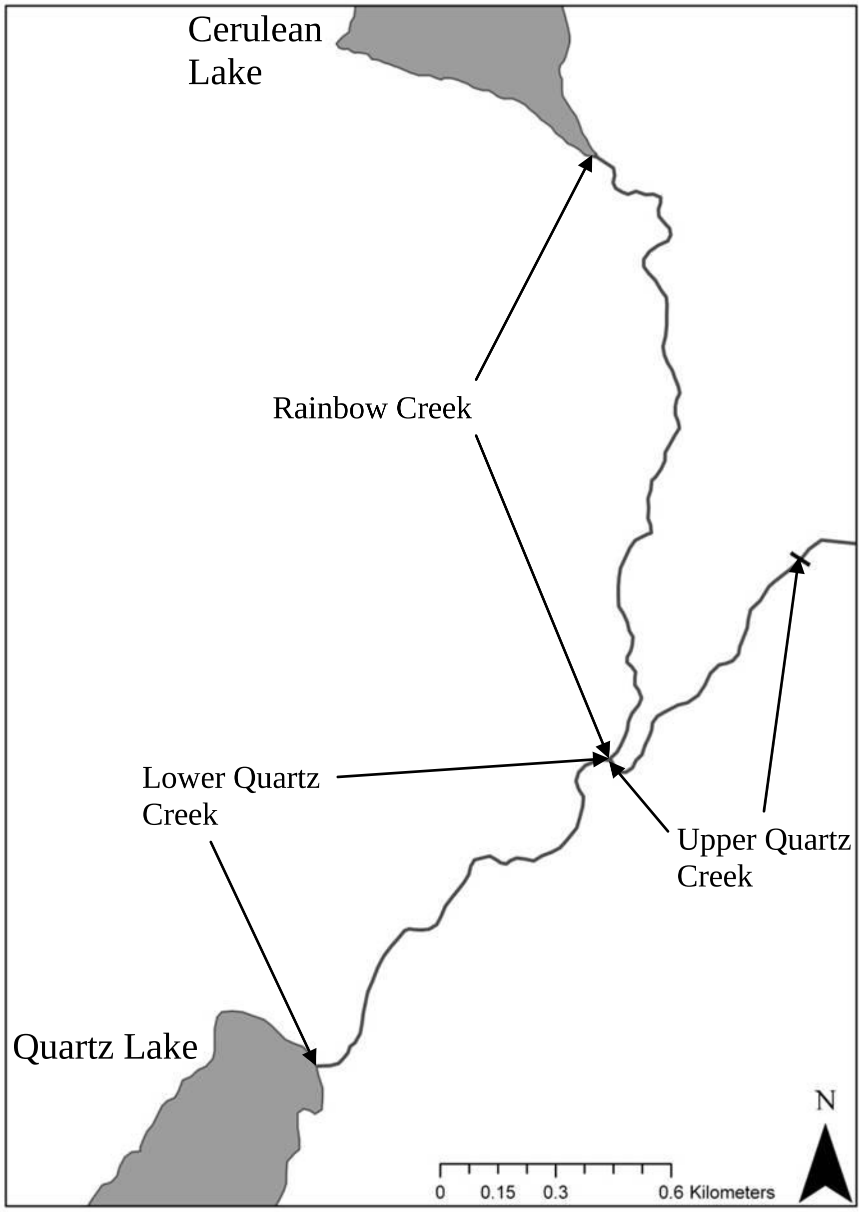


Figure 1 - Study area and stream segment designations in Glacier National Park, Montana. Stream segment designations (lower Quartz Creek, upper Quartz Creek, and Rainbow Creek) were based on stream hydrology and order.

Temperature and Discharge

Water temperature (°C) was monitored with a temperature data logger (Onset Computer Corporation, Bourne, Massachusetts) that was anchored to the substrate in the stream channel immediately upstream of the inlet of Quartz Lake. Stream temperature was recorded every 2 h from August 5 through October 11.

Stage (water height, m) was monitored with a data-logging staff gauge (TruTrack, Ltd., New Zealand; Model WT-HR) that was placed in lower Quartz Creek in a low-velocity area next to the stream bank. Stage was recorded every 2 h from August 5 through October 11, except during the period of September 16-23 when no data were recorded because of equipment failure. The staff gauge was relocated and reinstalled on September 24.

Stream discharge (m^3/s) was measured biweekly from August 5 through October 11 at a site in Quartz Creek downstream of the staff gauge to develop a stage–discharge relationship (Buchanan and Somers 1969). Discharge was calculated from stream velocity (m/s) measurements taken at 60% of the stream depth at each 0.2 m increment across the stream channel (Gallagher and Stevenson 1999). Stage-discharge relationships were established using simple linear regression (initial gauge site: $R^2 = 0.99$; relocated gauge site: $R^2 = 0.95$).

Physical Habitat Characteristics

Physical habitat surveys (modified from Gresswell et al. 2006) were conducted from August 7 through August 13 throughout the Quartz Lake drainage. Habitat units were identified starting at the inlet of Quartz Lake and proceeded upstream. Each habitat unit in both mainstem and side channel areas was classified as a pool, riffle, glide, or rapid (Bisson et al. 1982).

Length (nearest 0.1 m) of each habitat unit was measured, and maximum wetted width (nearest 0.5 m) was visually estimated. Actual maximum wetted width (nearest 0.1 m) was measured every tenth habitat unit, and a correction factor for visual estimates was established using simple linear regression (R^2 = 0.94; Hankin and Reeves 1988). Maximum depth (nearest 0.1 m) was measured in each pool using a surveying rod. Substrate composition in each habitat unit was visually estimated as percent silt, sand, gravel, cobble, boulder, and bedrock (Moore et al. 2002). Cover type was visually estimated for each habitat unit as the percent of the habitat unit occupied by large woody debris, boulder, alcove, overhanging vegetation, and backwater (Kaufmann et al. 1999). Undercut bank was measured as the percent of the habitat unit bank with an undercut greater than 0.2 m. Physical habitat characteristics in both mainstem and side channel habitat units were averaged by stream segment and 95% confidence intervals were used to evaluate differences in mean habitat characteristics among stream segments.

Spatial Distribution of Bull Trout Redds

Temporal variations in the occurrence of spawning were assessed with redd surveys conducted every other day from September 16 through October 11. If a survey was precluded because of inclement weather, it was conducted on the next suitable day. Redd surveys occurred in a section of Quartz and Rainbow creeks that had previously been established as an index reach because it encompassed the area assumed to have the greatest bull trout redd density (Figure 2; Meeuwig and Guy 2007). Newly constructed redds were identified and geospatially referenced while observers walked upstream along

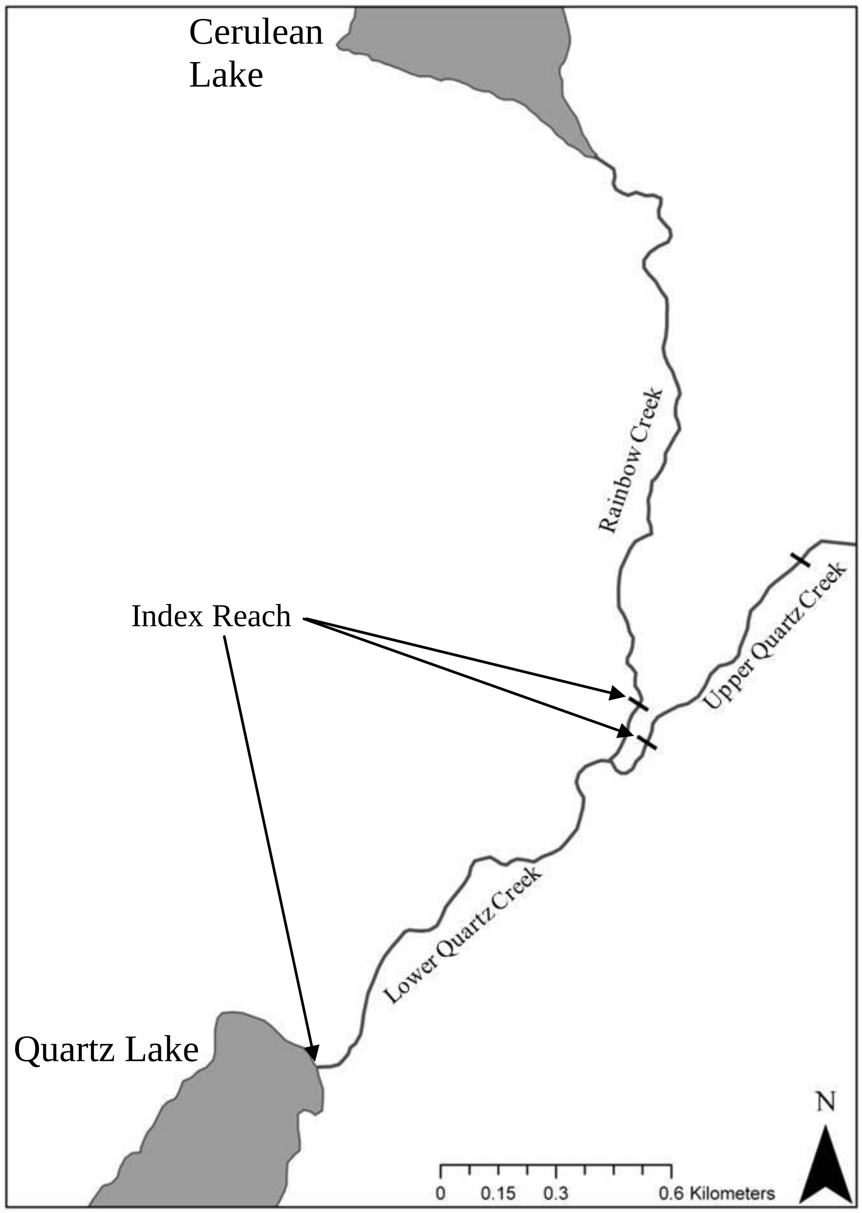


Figure 2 - Index reach designated for bull trout redd surveys in the study area, Glacier National Park, Montana.

the stream channel on each survey day. A brightly painted washer was placed in close proximity to newly identified redds to avoid double counting redds. Habitat units that contained at least one redd were marked by attaching flagging to nearby vegetation. Each subsequent observation of a new redd in the same habitat unit was recorded on the flagging.

In order to assess the spatial distribution of redds in the Quartz Lake drainage, redd surveys were conducted on October 1 and October 11 in Rainbow Creek upstream of the index reach to the outlet of Cerulean Lake and on October 6 in upper Quartz Creek upstream of the index reach to the putative fish barrier (Figure 2). Referencing and identification procedures were the same as those used for the index reach.

Geospatial coordinates of redd locations were integrated with a National Agriculture Imagery Program Orthoimagery layer (NAIP; UTM projected coordinate system, NAD 1983) and a digital elevation model (DEM; NAD 1983) of the study area using ArcGIS 9 software (Environmental Systems Research Institute, Inc., Reading, California; ArcMap Version 9.2). The elevation (m) of each redd and stream distance (m) of each redd from the inlet of Quartz Lake were measured using ArcGIS 9. Water temperature, discharge, and the number of new redds per survey were plotted by survey day to investigate variation in these parameters at the beginning, peak, and end of the spawning period. Redd locations, measured as the distance from the inlet of Quartz Lake, were plotted by survey day to investigate temporal and longitudinal trends in redd accumulation.

Redd data gathered outside of the index reach were combined with redd data from the index reach to estimate total redd accumulation and spatial distribution of redds. The cumulative frequency of redds was plotted as a function of the distance from the inlet of Quartz Lake to evaluate longitudinal trends in redd accumulation. Elevation of each redd was plotted as a function of distance from the inlet of Quartz Lake to investigate the change in elevation associated with redd location. Physical habitat characteristics measured in lower Quartz Creek, upper Quartz Creek, and Rainbow Creek were compared to the number of redds identified in each stream segment to investigate the relationship between stream habitat and redd abundance.

Subadult Bull Trout Presence and Distribution

Single-pass backpack electrofishing was used to determine the distribution of subadult bull trout throughout the Quartz Lake drainage. Sampling for subadult bull trout occurred August 14 through 28 at base flow and prior to movement of adult bull trout into the Quartz Lake drainage to spawn.

Electrofishing locations were selected using a systematic sampling design with two random starting points (Hansen et al. 2007). Pools and glides were grouped as slow water habitat units, and riffles and rapids were grouped as fast water habitat units (Arend 1999). Every fourth slow water unit and every fifth fast water unit were sampled for subadult bull trout. Habitat units selected for electrofishing were geospatially referenced and marked with a unique identifier during physical habitat surveys. All salmonids (i.e., bull trout and westslope cutthroat trout) sampled during electrofishing were identified to species, measured for total length (nearest mm total length), and returned to the habitat unit where they were collected.

A length-frequency histogram was used to estimate age structure of subadult bull trout. Subadult bull trout and westslope cutthroat trout occurrence (i.e., presence or absence) was designated for each habitat unit sampled. Occurrence was plotted as a function of habitat unit type (i.e., slow water or fast water) by stream segment for both species. The cumulative frequency of subadult bull trout and westslope cutthroat trout was plotted as a function of the distance from the inlet of Quartz Lake to evaluate differences in the distributions of these species in mainstem habitat in lower Quartz Creek and Rainbow Creek.

Subadult bull trout presence and abiotic habitat unit characteristics were examined using 11 competing multiple logistic regression models (Table 1). All models included the explanatory variables unit type (i.e., slow water or fast water) and stream gradient (Table 1) because of their assumed importance in predicting subadult bull trout presence. Additional explanatory variables included coarse substrate (i.e., the sum of percent gravel, cobble, and boulder), width (i.e., habitat unit maximum wetted width), percent large woody debris, and percent undercut bank (Table 1). Stream gradient was estimated at 100-m intervals starting at the beginning of each stream segment using ArcGIS 9 software. All habitat units located in the 100-m interval were assigned the resulting gradient value. Competing models were ranked based on Akaike's Information Criterion (Akaike 1973) adjusted for small sample size (AIC_c; Hurvich and Tsai 1989) using Program R, Version 2.8.1, package qpcR (Spiess and Ritz 2009). Delta (Δ) AIC_c values were calculated and models with ΔAIC_c values ≤ 2.0 were considered for inferences (Burnham and Anderson 2002). Model parameter estimates and adjusted coefficients of determination (Nagelkerke 1991) were estimated in Program R (Version 2.8.1), using package Design (Harrell 2008).

Table 1 – Subadult bull trout presence model number and the variables in the model for 11 combinations of variables used to examine subadult bull trout occurrence within tributaries to Quartz Lake, Glacier National Park, Montana.

Model	Explanatory variables in model
1	Unit type, gradient, coarse substrate, width, large woody debris, undercut bank
2	Unit type, gradient, coarse substrate, width, large woody debris
3	Unit type, gradient, coarse substrate, width, undercut bank
4	Unit type, gradient, coarse substrate, width
5	Unit type, gradient, coarse substrate, large woody debris
6	Unit type, gradient, coarse substrate, undercut bank
7	Unit type, gradient, coarse substrate
8	Unit type, gradient, width
9	Unit type, gradient, large woody debris
10	Unit type, gradient, undercut bank
11	Unit type, gradient

RESULTS

Physical Habitat Characteristics

Mainstem and side channel habitat were present in lower Quartz Creek and Rainbow Creek; only mainstem habitat was present in upper Quartz Creek. Side channel habitat units comprised 71 of 142 (50.0%) habitat units in lower Quartz Creek and 31 of 140 (22.1%) habitat units in Rainbow Creek. Habitat unit length, maximum wetted width, and maximum pool depth were similar among stream segments with the exception that the maximum wetted width of upper Quartz Creek was less than that of lower Quartz Creek and Rainbow Creek (Table 2). The dominant substrate type among stream segments was either gravel or cobble (Table 2). Additionally, lower Quartz Creek had the greatest percent of sand (19.5%), and Rainbow Creek had the greatest percent of boulder substrate (29.5%; Table 2). A low percentage of silt and bedrock substrate was documented in all three stream segments (Table 2). Large woody debris and undercut banks were the most common cover types in all stream segments; other cover types were rare. Undercut bank was the most common cover type in lower and upper Quartz Creek (18.6% and 22.8% respectively; Table 2). Rainbow Creek had the least amount of cover present among stream segments (<10.2% for each cover type measured; Table 2).

Table 2 – Mean (±95% CL) habitat unit abiotic characteristic by stream segment sampled in Glacier National Park, Montana. Biotic characteristic totals by stream segment sampled in Glacier National Park, Montana. Lower Quartz Creek included Quartz Creek from the inlet of Quartz Lake to the confluence of Quartz and Rainbow creeks and upper Quartz Creek included Quartz Creek upstream from the confluence of Quartz and Rainbow creeks to a putative fish barrier.

		Stream segment		
	Abiotic/biotic characteristic	Lower Quartz Creek	Upper Quartz Creek	Rainbow Creek
	Length (m)	15.3 ± 2.0	16.5 ± 5.7	16.6 ± 2.7
	Maximum wetted width (m)	6.3 ± 1.0	4.0 ± 0.3	5.2 ± 0.5
	Maximum pool depth (m)	0.8 ± 0.1	0.8 ± 0.1	0.7 ± 0.1
Substrate type (%)	Silt	3.2 ± 1.6	0.8 ± 1.4	1.6 ± 1.4
	Sand	19.5 ± 3.2	10.2 ± 3.7	4.6 ± 1.7
	Gravel	49.9 ± 3.5	40.6 ± 5.0	23.5 ± 3.8
	Cobble	26.4 ± 4.4	44.7 ± 7.2	36.0 ± 3.3
	Boulder	0.3 ± 0.3	3.8 ± 3.2	29.5 ± 4.6
	Bedrock	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Cover type (%)	Large woody debris	14.8 ± 2.4	10.4 ± 3.2	6.4 ± 1.5
	Undercut bank	18.6 ± 4.1	22.8 ± 8.8	10.2 ± 3.6
	Boulder	0.0* ± 0.1	0.2 ± 0.4	4.7 ± 1.0
	Alcove	0.4 ± 0.4	0.0 ± 0.0	0.0 ± 0.0
	Overhanging vegetation	2.9 ± 1.6	4.7 ± 3.6	1.9 ± 1.3
	Backwater	1.1 ± 0.8	0.3 ± 0.5	2.5 ± 2.0
	Redd count	61	2	30
	Subadult bull trout count	46	1	10
	Westslope cutthroat trout count	18	2	52

*value < 0.05

<u>Spatial Distribution of Bull Trout Redds</u>

All bull trout redds were observed in mainstem habitat (i.e., side channel habitat was not used for spawning). Bull trout redds were observed in all stream segments; 61 in lower Quartz Creek, two in upper Quartz Creek, and 30 redds in Rainbow Creek (Table 2). Lower Quartz Creek was characterized by relatively wider habitat units, high percentages of sand, gravel, and cobble substrate types and high percentages of large woody debris and undercut bank cover types (Table 2). Upper Quartz Creek was characterized by significantly narrower habitat units, high percentages of gravel and cobble substrate types, and a high percent of undercut bank cover type (Table 2). Rainbow Creek was characterized by moderately wide habitat units, high percentages of gravel, cobble, and boulder substrate types, and relatively low percentages of cover (Table 2).

Spawning was first documented on September 23, and peak spawning occurred on October 3 (Figure 3). October 11 was assumed to be the end of the spawning period because only two new redds were documented in the index reach and water temperature

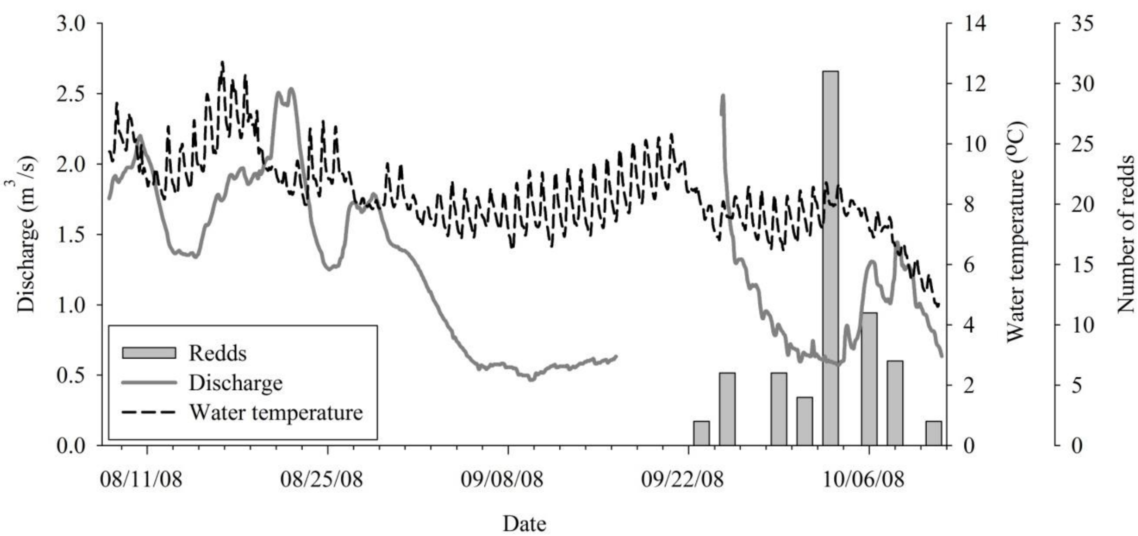


Figure 3 – Discharge, water temperature, and number of new bull trout redds in the Quartz Creek redd survey index reach upstream of Quartz Lake, Glacier National Park, Montana.

was below 6°C near the inlet of Quartz Lake (Figure 3). The assumed last date of spawning was preceded by two days of inclement weather that were unsuitable for lake travel, and previous surveys indicated that spawning activity was decreasing.

The number of new redds observed varied with time; however, there was no apparent relationship between the number of new redds and the distance from Quartz Lake (i.e., the number of redds did not increase upstream with time; Figure 4).

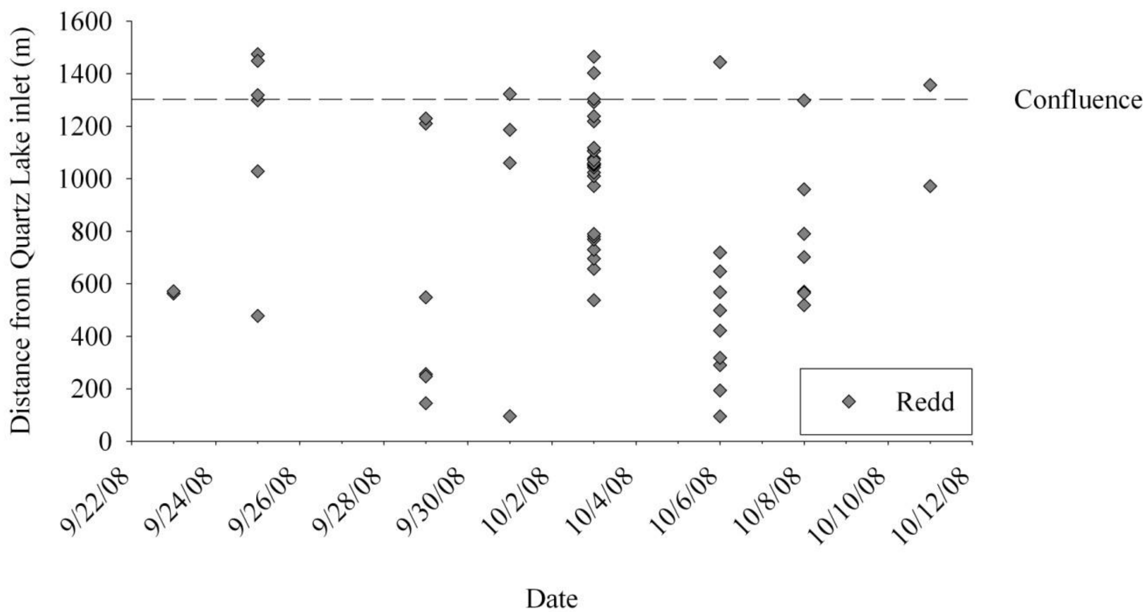


Figure 4 – Distance of each bull trout redd from the Quartz Lake inlet and its associated date of detection in the Quartz Creek redd survey index reach upstream of Quartz Lake, Glacier National Park, Montana. The confluence of Quartz and Rainbow creeks occurs at 1303 m.

Ninety-eight percent of all redds (91 of 93) were located in lower Quartz Creek and Rainbow Creek; lower Quartz Creek contained 65% of redds (61 of 91) detected in these two segments (Table 2; Figure 5). Only two redds were located in upper Quartz Creek. Fourteen redds were observed within about 450 m of the outlet of Cerulean Lake;

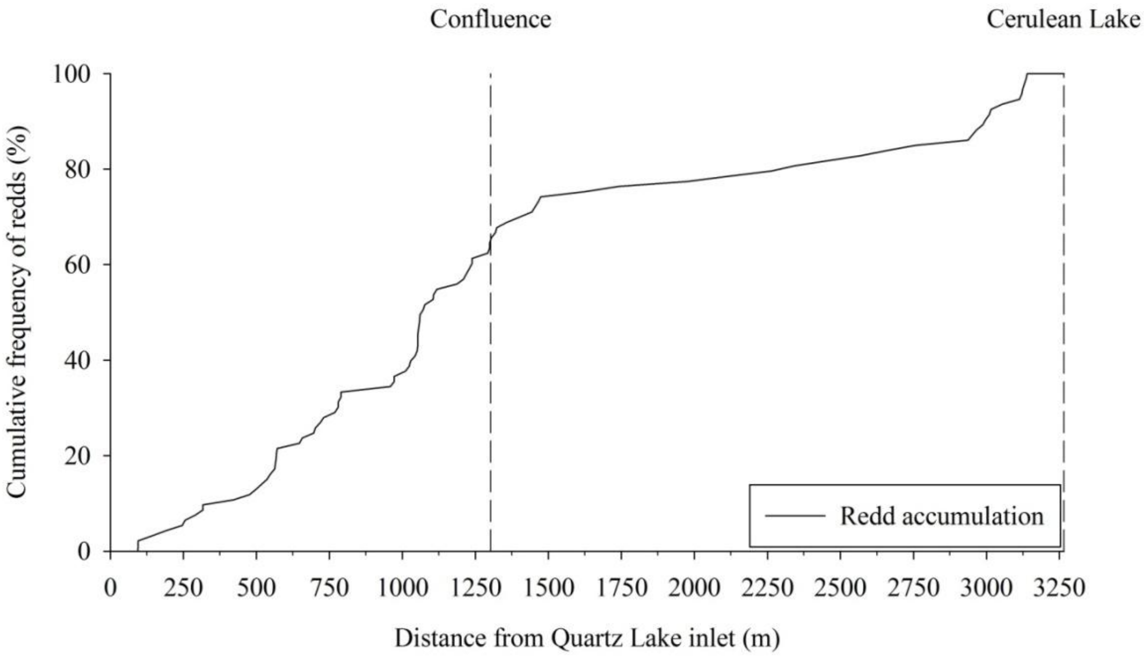


Figure 5 – Bull trout redd accumulation (cumulative frequency of redds as a function of distance) in lower Quartz Creek (0 to 1303 m from the Quartz Lake inlet) and Rainbow Creek (1303 to 3265 m from the Quartz Lake inlet), Glacier National Park, Montana. The confluence of Quartz and Rainbow creeks occurs at 1303 m.

spawning activity had not been documented in Rainbow Creek near the outlet of Cerulean Lake prior to this study.

Elevation increases with distance from the Quartz Lake inlet upstream to the outlet of Cerulean Lake (Figure 6). There were more redds in low-stream gradient areas, including Lower Quartz Creek (0 to 1300 m) and Rainbow Creek near the outlet of Cerulean Lake (about 2800 to 3200 m; Figure 6). Alternatively, in areas of high stream gradient, fewer redds were observed (e.g., Rainbow Creek from about 1500 m to 3000 m; Figure 6).

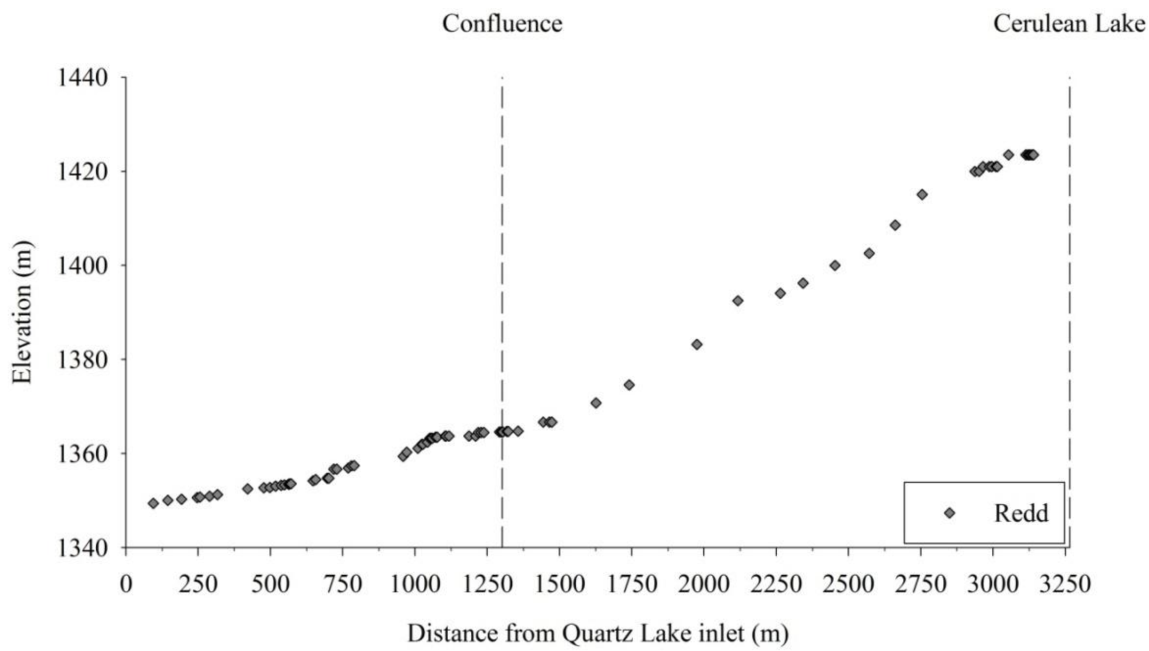


Figure 6 – Elevation of each bull trout redd in lower Quartz Creek (0 to 1303 m from the Quartz Lake inlet) and Rainbow Creek (1303 to 3265 m from the Quartz Lake inlet), Glacier National Park, Montana. The confluence of Quartz and Rainbow creeks occurs at 1303 m.

Subadult Bull Trout Presence and Distribution

Fifty-seven subadult bull trout and 72 westslope cutthroat trout were sampled in 87 habitat units in the Quartz Lake drainage; however, subadult bull trout were most abundant in lower Quartz Creek, and westslope cutthroat trout were most abundant in Rainbow Creek (Table 2). Lower Quartz Creek contained about 75% of the subadult bull trout sampled and only about 20% of the westslope cutthroat trout sampled in mainstem habitat (Figure 7). Although subadult bull trout and westslope cutthroat trout were sampled in both fast and slow water habitat units, both species were more frequently found in slow water habitat units; neither species was sampled from fast water habitat units in upper Quartz Creek (Figure 8 a and b).

Subadult bull trout varied in length from 44 to 167 mm. At least two age groups of subadult bull trout were present within the Quartz Lake drainage as evidence by two distinct peaks (40-65 mm and 95-125 mm) in the length-frequency histogram (Figure 9). These groups are likely age-0 and age-1 fish based on data from bull trout populations in the Flathead River Basin (Fraley and Shepard 1989).

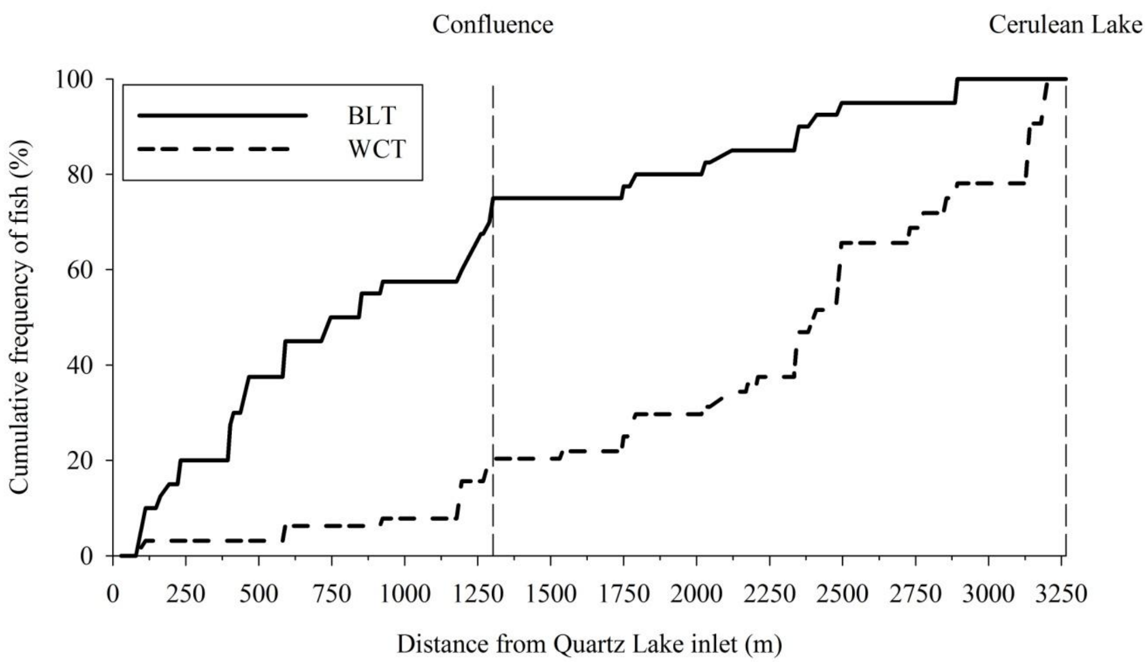
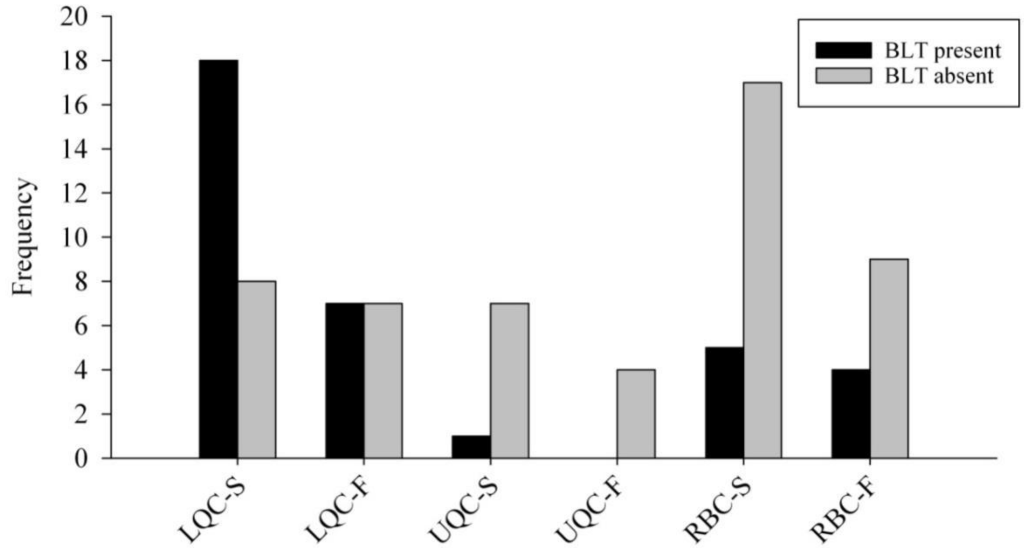


Figure 7 – Cumulative frequency of subadult bull trout and westslope cutthroat trout in mainstem habitat in lower Quartz Creek (0 to 1303 m from the Quartz Lake inlet) and Rainbow Creek (1303 to 3265 m from the Quartz Lake inlet), Glacier National Park, Montana. The confluence of Quartz and Rainbow creeks occurs at 1303 m.

a



b

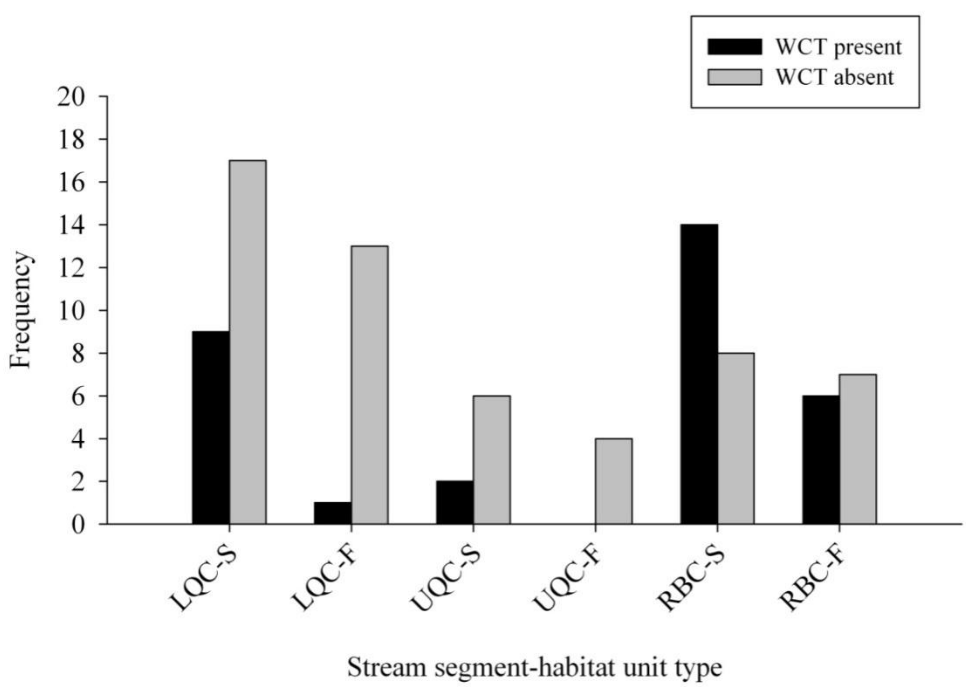


Figure 8 - Frequency of stream segments and habitat unit types with (a) subadult bull trout present and absent and (b) westslope cutthroat trout present and absent. Stream segments refer to lower Quartz Creek (LQC), upper Quartz Creek (UQC), and Rainbow Creek (RBC). Habitat unit types refer to slow water habitat units (-S; i.e., pools or glides) and fast water habitat units (-F; i.e., riffles or rapids).

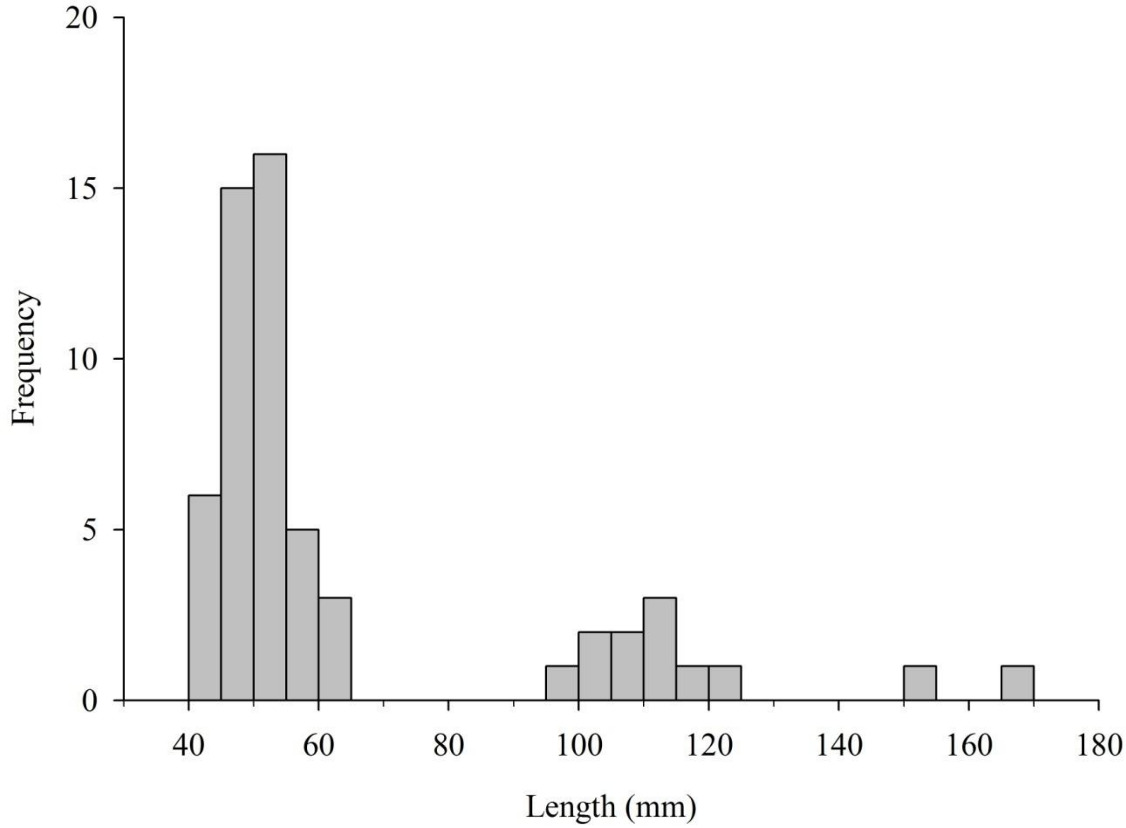


Figure 9 – Length-frequency histogram of subadult bull trout sampled within the Quartz Lake drainage, Glacier National Park, Montana.

Three of the 11 subadult bull trout presence models were considered for inference (Table 3). All models considered had ΔAIC_c values of ≤ 2.0, except the third ranked model which had a ΔAIC_c value of 2.01, but this model was considered because the associated ΔAIC_c value was within 0.01 of the 2.0 limit (Table 3). The most likely model of subadult bull trout presence suggested that subadult bull trout presence is best explained by the variables unit type (i.e., slow water or fast water) and gradient (stream gradient) which were included in all competing models, and the addition of coarse substrate (sum of percent gravel, cobble, and boulder) and width (habitat unit maximum wetted width; Table 3). The other models considered for inference included similar explanatory variables, with the inclusion of large woody debris in the third ranked model (Table 3). The evidence ratio (w_1/ w_j) suggests the highest ranked model was 1.37 times more likely than the second ranked model and 2.73 times more likely than the third ranked model (Table 3). Parameter estimates from multiple logistic regression analysis for each model suggest that gradient and coarse substrate are negatively associated with subadult bull trout presence; whereas, unit type, width, and large woody debris are positively associated with subadult bull trout presence (Table 4). However, the variables included in the top ranked models accounted for a relatively low proportion of the variability in bull trout presence; Nagelkerke's adjusted R^2 = 0.21 for the first and third ranked models and R^2 = 0.17 for the second ranked model (Table 4).

Table 3 – Subadult bull trout presence model rank, model number, Akaike's Information Criterion adjusted for small sample size (AIC_c), AIC_c differences (ΔAIC_c), and evidence ratio (w_1/ w_j) for comparing models used to examine abiotic effects on subadult bull trout occurrence in the Quartz Lake drainage, Glacier National Park, Montana.

Rank	Model	Explanatory variables in model	AIC_c	ΔAIC_c	w_1/ w_j
1	4	Unit type, gradient, coarse substrate, width	113.97	0.0	
2	8	Unit type, gradient, width	114.60	0.63	1.37
3	2	Unit type, gradient, coarse substrate, width, large woody debris	115.98	2.01	2.73

Table 4 – Subadult bull trout presence model rank, model number, model parameters, parameter estimates, parameter estimate standard errors, parameter estimate *P*-values, and model R^2 values used to examine abiotic effects on subadult bull trout occurrence in the Quartz Lake drainage, Glacier National Park, Montana.

Rank	Model	Model parameter	Parameter estimate	Standard error	*P*-value	R^2
1	4	Intercept	0.020	1.369	0.988	0.21
		Unit type = slow water	0.081	0.531	0.879	
		Gradient	-3.090	11.671	0.791	
		Coarse substrate	-0.024	0.015	0.097	
		Width	0.311	0.105	0.003	
2	8	Intercept	-1.955	0.739	0.008	0.17
		Unit type = slow water	0.383	0.496	0.440	
		Gradient	-8.596	11.111	0.439	
		Width	0.274	0.097	0.005	
3	2	Intercept	-0.471	1.584	0.766	0.21
		Unit type = slow water	0.023	0.543	0.966	
		Gradient	-1.759	11.927	0.883	
		Coarse substrate	-0.021	0.015	0.158	
		Width	0.328	0.111	0.003	
		Large woody debris	0.014	0.024	0.549	

DISCUSSION

Lacustrine-adfluvial bull trout occupy numerous headwater lakes in Glacier National Park. Results of this study provide important new information pertaining to the spawning and rearing characteristics of lacustrine-adfluvial bull trout in the Quartz Lake drainage upstream of Quartz Lake. Prior to this study, there was a lack of data detailing the spatial and temporal distribution of bull trout redds and the spatial distribution and habitat association of subadult bull trout rearing in tributary streams in headwater lake habitat.

Bull trout redds were present throughout the Quartz Lake drainage; however, the highest number of redds were observed in lower Quartz Creek. These data suggest that lower Quartz Creek provides the best spawning habitat within the Quartz Lake drainage. High percentages of gravel and cobble substrate types and relatively low stream gradient characterize lower Quartz Creek. Similarly, bull trout throughout the Flathead River drainage spawn in areas characterized by gravel substrate, low compaction, and low gradient; additionally, spawning sites are generally located close to cover in areas with groundwater influence (Fraley and Shepard 1989). Although, groundwater influence was not measured in the Quartz Lake drainage, it is suspected that groundwater exchange plays an important role in bull trout spawning site selection (Baxter and Hauer 2000) and egg and fry survival (Baxter and McPhail 1999). In the Quartz Lake drainage, distance of redds from cover was not directly measured in the field, but numerous redds were found within close proximity to large woody debris or overhanging vegetation, which is consistent with previous findings (McPhail and Murray 1979; Fraley and Shepard 1989).

Rainbow Creek is about 660 m longer than lower Quartz Creek; however, there were fewer redds located in Rainbow Creek than in lower Quartz Creek. The majority of redds in Rainbow Creek were located within about 275 m of the confluence of Quartz Creek and Rainbow Creek, or within about 450 m of the outlet of Cerulean Lake. These areas were characterized by relatively low stream gradient and a high percentage of gravel and cobble substrate. The remaining redds in Rainbow Creek were observed in a 1200 m stream section characterized by relatively higher gradients and a greater percent of boulder substrate. Individual redds in this section were located in slow water habitat units (e.g., pools) with gravel and cobble substrate. These patterns further suggest that bull trout within the Quartz Lake drainage are selecting areas of lower gradient with high percentages of gravel and cobble substrate.

Upper Quartz Creek was also characterized by high percentages of gravel and cobble substrate, but only two redds were observed in this stream segment. It was apparent that a large portion of the stream channel in this stream segment was recently affected by flood or debris flow, and a new channel was developing. In 2004, redds were observed in the old stream channel adjacent to the current one (Meeuwig and Guy 2007). If this recent disturbance is related to a reduced level of bull trout spawning activity in upper Quartz Creek, it is possible that spawning activity will increase if the new channel stabilizes in future years.

Spawning commenced once water temperatures were continuously less than 9°C, and water temperatures were 5-6°C by the time spawning was considered to be complete. However, there were periods of time prior to the initiation of bull trout spawning when water temperature were less than 9°C for a few days before increasing above 9°C, and bull trout spawning did not commence. This pattern suggests that water temperature may not be the only cue for commencement of bull trout spawning. This finding is consistent with previous studies that suggest the initiation of spawning is related to a complex interaction of photoperiod, stream discharge, and water temperature (Fraley and Shepard 1989; Brenkman et al. 2001). Unfortunately, stream discharge data were unavailable at the time when bull trout commenced spawning in the Quartz Lake drainage.

Westslope cutthroat trout also are found within the Quartz Lake drainage. The native distributions of bull trout and westslope cutthroat trout species overlap, and westslope cutthroat trout occur sympatrically with bull trout in portions of the Flathead River drainage in northwest Montana (Fredenberg 1997). Subadult bull trout and westslope cutthroat trout were present in each stream segment, but both species were rare in upper Quartz Creek. Evaluation of cumulative frequency data for both species in mainstem habitat in lower Quartz Creek and Rainbow Creek indicates that the abundance of these species may be negatively related. For example, the majority of subadult bull trout sampled occupied habitat units in lower Quartz Creek, but the majority of westslope cutthroat trout sampled occupied habitat units in Rainbow Creek. Therefore, this may be indicative of habitat partitioning or variability in preference for particular microhabitat by each species (e.g., Nakano et al. 1998).

Subadult bull trout were sampled in both slow water and fast water habitat units in Quartz Lake drainage; they occurred most frequently in slow water habitat units in lower Quartz Creek. Apparently, subadult bull trout are selecting for habitat types with low water velocities, such as pool habitat. Similar relationships have been observed in other studies. For example, in the Clearwater River drainage, Idaho, subadult bull trout were generally associated with low water velocities (Spangler and Scarnecchia 2001), and in the Flathead River system, subadult bull trout used pools more frequently than runs, riffles, or pocket water (Fraley and Shepard 1989).

Length-frequency data suggest that two distinct age classes of subadult bull trout (most likely age 0 and age 1) were present within the Quartz Lake drainage, and only two individuals with total lengths of 151 and 167 mm appear to be older than age 1. Electrofishing is generally biased towards sampling larger fish (Reynolds 1996); therefore, the assessment of subadult bull trout length-frequency in the Quartz Lake drainage is probably reliable. In the larger streams of the Flathead River drainage, subadult bull trout remain in tributaries for 1-3 years before emigrating to mainstem Flathead River habitats (Fraley and Shepard 1989), but in Trestle Creek, a tributary to Lake Pend Oreille, Idaho, thousands of age-0 bull trout emigrated during high spring flows (Downs et al. 2006).

Research suggests that subadult bull trout are often found in close proximity to the streambed (Polacek and James 2003). Additionally, a large majority of studies that investigated subadult bull trout habitat associations conclude that pool or low water velocity habitat (Fraley and Shepard 1989; Bonneau and Scarnecchia 1998; Thurow 2006) and cover such as large woody debris (Dambacher and Jones 1997; Muhlfeld and Marotz 2005) or undercut bank (Dambacher and Jones 1997) are important at this life-history stage. Subadult bull trout are also reported to have a positive relationship with coarse substrates (Dambacher and Jones 1997; Muhlfeld and Marotz 2005; Thurow 2006).

In the present study, subadult bull trout presence was positively related to slow water habitat units and habitat unit maximum wetted width, and negatively related to stream gradient and coarse substrate. While sampling, subadult bull trout were frequently observed in low gradient areas with large woody debris, and large woody debris was included as a predictor variable in the third highest ranked model explaining subadult bull trout presence. Similarly, bull trout presence was positively related to large woody debris and channel width in the Bitterroot River drainage (Rich et al. 2003). In that same study, bull trout presence was negatively related to gradient (Rich et al. 2003). Coarse substrate, in the previously mentioned studies, had a positive relationship with subadult bull trout presence; however, the opposite was suggested by the present study. For the model selection and multiple logistic regression analyses, coarse substrate was defined as the sum of percent gravel, cobble, and boulder for reasons pertaining to model simplicity; this may mask untested relationships between subadult bull trout and each individual substrate type.

Three statistical models were identified as having the greatest support given the data. However, evaluation of the selected models with multiple logistic regression revealed that the selected models explained a relatively small proportion of the variability in subadult bull trout presence. Regardless of the relatively poor model fit, patterns in the presence of subadult bull trout and the distribution and accumulation of bull trout redds were very similar. The majority of bull trout redds and subadult bull trout were found in lower Quartz Creek, suggesting that this stream segment is important for both spawning and rearing. Characteristics of this stream segment that likely make it productive for bull trout spawning included low gradient and high percentages of gravel and cobble substrates, and likely groundwater exchange. However, it is not clear from the multiple logistic regression models what physical habitat characteristics are most important for subadult bull trout at the habitat unit scale.

Information is lacking on spawning and early life-history characteristics of bull trout occupying headwater-lake ecosystems. This study helped “fill a gap” in what is known about these headwater-lake bull trout populations, and it identified areas of adult and subadult bull trout use in tributaries to Quartz Lake, which provides information that will allow Glacier National Park biologists to better manage and monitor bull trout in the Quartz Lake. Additionally, the data presented here may be used as a benchmark for management and restoration goals following mitigation or removal of threats posed by the presence of nonnative lake trout in Quartz Lake. The information gathered from this study may also be applicable for restoration efforts in other headwater lake systems within Glacier National Park and the surrounding area.

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APPENDICES

APPENDIX A

2008 STREAM SEGMENT AND REACH GEOSPATIAL COORDINATES

Appendix A – Stream reach geospatial coordinates (UTM) for 2008 in Lower Quartz Creek (LQC), Upper Quartz Creek (UQC), and Rainbow Creek (RNB), tributaries to Quartz Lake, Glacier National Park, Montana.

		Start		End	
Segment	Reach	Easting UTM	Northing UTM	Easting UTM	Northing UTM
LQC	1	715387	5414702	715564	5415000
LQC	2	715564	5415000	715767	5415197
LQC	3	715767	5415197	715989	5415268
LQC	4	715989	5415268	716123	5415505
UQC	5	716123	5415505	716258	5415553
UQC	6	716258	5415553	716274	5415631
UQC	7	716274	5415631	716487	5415842
UQC	8	716487	5415842	716559	5415954
RNB	9	716559	5415954	716193	5415611
RNB	10	716193	5415611	716215	5415715
RNB	11	716215	5415715	716227	5416780
RNB	12	716227	5416780	716275	5416965
RNB	13	716275	5416965	716115	5417072

APPENDIX B

2008 PHYSICAL HABITAT CHARACTERISTICS

Appendix B – Physical habitat measured in 2008 for Lower Quartz Creek (LQC), Upper Quartz Creek (UQC), and Rainbow Creek (RNB), tributaries to Quartz Lake, Glacier National Park, Montana. Grvl = Gravel, Cbbl = Cobble, Bldr = Boulder, Bdrk = Bedrock, LWD = large woody debris, UCB = undercut bank, BLD = boulder, ALC = alcove, OHV = overhanging vegetation, BKW = backwater, P = pool, R = riffle, G = glide, C = rapid, S- = side channel, LGJ = log jam.

						Subtrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
LQC	1	P	27.8	11.7	1.1	0	30	70	0	0	0	25	0	0	0	0	5
LQC	1	P	9.4	4.9	0.9	0	40	60	0	0	0	10	0	0	0	0	0
LQC	1	P	29.8	22.0	1.0	0	10	90	0	0	0	40	0	0	0	0	5
LQC	1	R	11.9	12.9	.	0	10	40	50	0	0	5	0	0	0	0	0
LQC	1	P	33.6	6.3	1.1	0	5	70	25	0	0	5	25	0	0	0	0
LQC	1	R	35.0	9.8	.	0	5	45	50	0	0	10	0	0	25	0	0
LQC	1	P	15.2	9.1	1.2	0	15	85	0	0	0	5	0	0	0	0	0
LQC	1	SP	18.6	3.7	0.7	10	40	50	0	0	0	0	0	0	20	15	0
LQC	1	SR	16.0	5.2	.	0	5	95	0	0	0	0	0	0	0	0	0
LQC	1	SP	7.3	3.7	0.5	0	45	55	0	0	0	10	0	0	0	0	0
LQC	1	SR	9.1	1.8	.	0	5	95	0	0	0	0	0	0	0	0	0
LQC	1	SP	14.0	2.6	0.4	0	50	50	0	0	0	0	5	0	0	5	0
LQC	1	R	29.7	10.7	.	0	10	45	45	0	0	0	0	0	0	0	15
LQC	1	P	6.9	8.2	.	0	0	50	50	0	0	20	0	0	0	0	0
LQC	1	R	22.7	7.9	.	0	10	45	45	0	0	5	0	0	5	0	0
LQC	1	P	10.0	12.7	0.7	0	40	60	0	0	0	15	0	0	0	0	10
LQC	1	R	10.9	9.0	.	0	0	50	50	0	0	10	0	0	0	0	0
LQC	1	P	12.3	10.1	0.8	0	0	50	50	0	0	15	0	0	0	0	0
LQC	1	R	7.9	15.5	.	0	0	40	60	0	0	0	0	0	0	0	5
LQC	1	P	4.7	8.4	0.9	5	10	60	25	0	0	20	0	0	0	0	0
LQC	1	R	5.9	10.6	.	0	0	0	100	0	0	20	0	0	0	0	0
LQC	1	P	11.0	9.9	0.8	0	5	45	50	0	0	5	75	0	0	0	0
LQC	1	R	19.8	6.1	.	0	10	40	50	0	0	20	5	0	0	0	10
LQC	1	P	11.8	6.9	1.0	5	5	70	20	0	0	20	50	0	0	0	0
LQC	1	P	14.0	4.5	0.7	0	10	60	30	0	0	15	50	0	0	0	0
LQC	1	R	7.5	6.5	.	0	0	30	70	0	0	10	0	0	0	0	0
LQC	1	P	5.9	3.5	0.8	0	30	70	0	0	0	30	0	0	0	0	0
LQC	1	R	6.2	5.0	.	0	0	50	50	0	0	10	0	0	0	0	0

Appendix B continued.

						Substrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
LQC	1	SR	6.3	5.5	.	0	0	40	60	0	0	5	0	0	0	0	0
LQC	1	SP	6.9	3.5	0.8	0	0	50	50	0	0	10	0	0	0	10	0
LQC	1	SR	7.8	5.5	.	0	5	45	50	0	0	15	0	0	0	5	10
LQC	1	SP	9.6	4.0	0.5	0	20	50	30	0	0	5	5	0	0	0	0
LQC	1	SR	8.0	3.9	.	0	0	50	50	0	0	0	0	0	0	45	0
LQC	1	SP	18.2	2.5	0.7	0	5	45	50	0	0	20	75	0	0	10	0
LQC	1	SP	23.4	7.5	0.9	0	50	50	0	0	0	30	50	0	0	0	0
LQC	1	SR	3.1	6.0	.	0	20	80	0	0	0	5	50	0	0	0	0
LQC	1	SP	12.2	5.5	0.8	0	40	60	0	0	0	15	10	5	0	0	0
LQC	1	SR	4.0	3.5	.	0	50	50	0	0	0	50	100	0	0	30	0
LQC	1	SP	7.2	3.7	0.7	0	75	25	0	0	0	20	50	0	0	0	5
LQC	1	SR	6.5	4.5	.	0	50	50	0	0	0	10	70	0	0	0	0
LQC	1	SP	9.6	2.5	0.7	10	80	10	0	0	0	30	90	0	0	0	0
LQC	1	SP	24.8	.	0.7	20	50	30	0	0	0	30	80	0	0	0	0
LQC	1	SP	13.5	2.9	0.8	40	60	0	0	0	0	25	70	0	0	0	0
LQC	1	SP	14.9	2.5	0.7	50	50	0	0	0	0	50	90	0	0	0	0
LQC	1	SR	4.1	4.5	.	0	50	50	0	0	0	10	0	0	0	0	0
LQC	1	SP	10.8	3.5	0.7	5	15	60	20	0	0	10	30	0	0	0	0
LQC	1	SP	22.6	8.0	0.8	40	50	10	0	0	0	5	5	0	0	0	0
LQC	1	SP	5.8	2.5	0.5	10	50	40	0	0	0	0	40	0	0	0	0
LQC	1	SR	11.6	5.0	.	30	60	10	0	0	0	5	0	0	0	0	0
LQC	1	SP	34.0	3.0	0.5	30	60	10	0	0	0	15	10	0	0	0	0
LQC	1	SR	9.7	2.5	.	10	40	50	0	0	0	20	5	0	0	0	0
LQC	1	SP	12.8	2.5	0.4	50	20	30	0	0	0	30	60	0	0	0	0
LQC	1	SR	24.9	2.0	.	0	10	90	0	0	0	5	5	0	0	0	0
LQC	1	SP	8.3	2.5	0.5	10	40	50	0	0	0	30	0	0	0	15	0
LQC	1	SR	22.0	2.5	.	0	20	80	0	0	0	5	0	0	0	0	0
LQC	1	SP	6.7	2.5	0.5	30	40	30	0	0	0	25	0	0	0	0	0
LQC	1	SR	6.8	2.0	.	0	15	85	0	0	0	25	0	0	0	0	0
LQC	1	SP	4.8	1.5	0.4	30	30	40	0	0	0	50	25	0	0	0	0
LQC	1	SR	2.7	3.0	.	0	40	60	0	0	0	25	50	0	0	0	0
LQC	1	SP	10.2	.	.	20	40	40	0	0	0	15	50	0	0	0	0

Appendix B continued.

Segment	Reach	Unit type	Length	Width	Pool depth	Substrate type (Percent composition) Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	Cover type (Percent composition) LWD	UCB	BLD	ALC	OHV	BKW
LQC	1	SR	4.2	2.0	.	0	50	50	0	0	0	20	25	0	0	0	0
LQC	1	SP	5.2	2.0	0.4	0	30	70	0	0	0	30	50	0	0	0	0
LQC	1	SR	3.9	3.1	.	0	30	70	0	0	0	25	50	0	0	0	0
LQC	1	SP	8.9	3.5	0.8	0	50	50	0	0	0	30	80	0	0	0	0
LQC	1	SR	2.3	2.0	.	0	20	80	0	0	0	30	0	0	0	0	0
LQC	1	SP	11.0	3.0	0.5	0	50	50	0	0	0	20	40	0	0	0	0
LQC	1	SR	2.9	2.5	.	0	0	100	0	0	0	0	0	0	0	40	0
LQC	1	SP	19.5	4.0	0.5	10	20	70	0	0	0	20	50	0	0	0	0
LQC	1	SP	12.4	5.0	0.4	0	20	80	0	0	0	5	0	0	0	0	0
LQC	1	SR	14.7	3.5	.	0	5	95	0	0	0	10	0	0	0	0	0
LQC	1	SP	28.8	4.0	0.8	5	45	50	0	0	0	15	20	0	0	0	0
LQC	1	SR	3.4	2.0	.	0	10	90	0	0	0	5	0	0	0	0	0
LQC	1	SP	5.5	2.3	0.3	0	50	50	0	0	0	25	10	0	0	0	0
LQC	1	SR	7.3	1.5	.	0	50	50	0	0	0	15	30	0	0	0	0
LQC	1	SP	6.7	2.0	0.5	10	60	30	0	0	0	10	10	0	0	0	0
LQC	1	SR	19.2	1.0	.	0	30	70	0	0	0	10	0	0	0	0	0
LQC	1	SP	7.6	2.0	0.3	0	10	90	0	0	0	10	0	0	0	0	0
LQC	1	SR	38.5	2.0	.	0	10	90	0	0	0	10	0	0	0	0	0
LQC	1	SP	15.6	1.5	0.3	0	10	90	0	0	0	10	20	0	0	0	0
LQC	1	SR	10.0	1.0	.	0	10	90	0	0	0	10	40	0	0	0	0
LQC	1	SG	17.2	4.5	0.5	0	10	60	30	0	0	20	0	0	0	0	0
LQC	1	SP	20.7	5.0	0.7	0	30	70	0	0	0	5	10	0	0	0	0
LQC	1	SR	25.7	3.6	.	0	10	50	40	0	0	5	50	0	0	15	0
LQC	1	SR	5.6	2.0	.	0	10	90	0	0	0	0	0	0	0	0	0
LQC	1	SP	34.5	3.5	0.7	0	50	50	0	0	0	15	50	0	0	5	0
LQC	2	P	8.2	6.5	1.1	0	30	30	40	0	0	10	5	0	0	50	0
LQC	2	R	6.9	7.0	.	0	0	30	70	0	0	5	0	0	0	0	0
LQC	2	P	20.6	8.0	1.3	0	20	50	30	0	0	5	30	0	0	0	0
LQC	2	R	8.8	8.0	.	0	0	30	70	0	0	5	50	0	0	0	0
LQC	2	P	7.7	17.0	1.5	5	30	35	30	0	0	20	30	0	0	0	0
LQC	2	R	11.7	5.5	.	0	0	30	70	0	0	0	0	0	0	0	0
LQC	2	P	14.4	5.5	1.0	0	5	50	45	0	0	20	0	0	0	0	10

Appendix B continued.

						Substrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
LQC	2	R	8.7	11.2	.	0	0	50	50	0	0	0	30	0	0	0	5
LQC	2	P	29.5	10.5	1.1	0	30	40	30	0	0	5	30	0	0	10	0
LQC	2	R	26.4	10.0	.	0	5	45	50	0	0	5	20	0	0	0	0
LQC	2	P	19.6	20.0	0.7	0	20	50	30	0	0	70	30	0	0	20	0
LQC	2	P	25.4	9.5	1.1	0	40	50	10	0	0	30	40	0	0	0	0
LQC	2	R	11.7	11.0	.	0	5	35	60	0	0	10	0	0	0	0	0
LQC	2	P	2.5	18.0	0.6	0	10	30	60	0	0	15	0	0	0	0	0
LQC	2	R	29.2	15.0	.	0	5	50	45	0	0	5	30	0	0	0	0
LQC	2	P	10.2	14.0	1.2	0	10	50	40	0	0	35	20	0	0	0	0
LQC	2	SR	4.4	.	.	0	30	40	30	0	0	10	50	0	0	0	0
LQC	2	SP	13.0	1.8	0.4	5	10	65	20	0	0	15	20	0	0	5	0
LQC	2	SR	11.8	3.0	.	0	15	35	50	0	0	5	0	0	0	0	0
LQC	2	SP	11.9	3.5	.	0	20	40	40	0	0	20	0	0	0	0	0
LQC	2	R	23.7	7.5	.	0	0	50	50	0	0	5	40	0	0	5	0
LQC	2	P	12.8	4.5	0.9	0	0	50	50	0	0	5	50	0	0	60	0
LQC	2	R	17.0	13.0	.	0	0	30	70	0	0	5	30	0	0	0	5
LQC	2	P	9.4	8.0	0.8	0	0	50	50	0	0	10	20	0	0	0	0
LQC	2	LGJ	16.2	.	.	0	0	0	0	0	0	0	0	0	0	0	0
LQC	2	R	20.6	10.0	.	0	0	40	60	0	0	30	0	0	0	0	0
LQC	3	R	23.2	10.5	.	0	0	50	50	0	0	0	0	0	0	0	0
LQC	3	P	31.6	5.3	1.3	0	10	70	20	0	0	15	50	0	0	0	0
LQC	3	R	12.4	7.0	.	0	0	30	70	0	0	10	0	0	0	0	0
LQC	3	P	12.3	5.5	0.8	0	5	70	25	0	0	5	5	0	0	0	5
LQC	3	R	11.3	8.0	.	0	0	50	50	0	0	5	0	0	0	0	0
LQC	3	P	10.9	8.0	1.1	0	15	35	50	0	0	10	0	0	0	0	0
LQC	3	SP	8.3	5.0	0.8	0	30	60	10	0	0	10	30	0	0	0	0
LQC	3	SR	16.1	5.0	.	0	20	60	20	0	0	10	40	0	0	0	20
LQC	3	SP	13.3	6.0	0.8	20	40	40	0	0	0	10	0	0	0	0	50
LQC	3	R	9.3	4.5	.	0	0	50	50	0	0	5	0	0	0	0	0
LQC	3	P	7.5	9.0	1.1	0	20	60	20	0	0	5	0	0	0	0	0
LQC	3	R	11.8	7.5	.	0	0	30	70	0	0	0	0	0	0	0	0
LQC	3	P	13.5	8.0	1.0	0	30	40	30	0	0	80	0	0	0	0	0

Appendix B continued.

Segment	Reach	Unit type	Length	Width	Pool depth	Substrate type (Percent composition) Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	Cover type (Percent composition) LWD	UCB	BLD	ALC	OHV	BKW
LQC	3	R	7.7	6.0	.	0	0	20	80	0	0	0	0	0	0	30	0
LQC	3	P	9.8	7.0	1.1	0	20	30	50	0	0	0	0	0	0	30	0
LQC	3	R	63.0	13.5	.	0	10	45	45	0	0	5	0	0	0	0	0
LQC	3	P	9.3	5.5	1.0	0	10	45	45	0	0	40	10	0	0	0	0
LQC	3	R	52.0	4.4	.	0	0	30	70	0	0	20	0	0	0	0	0
LQC	4	P	15.4	6.0	1.1	0	20	40	40	0	0	30	50	0	0	0	0
LQC	4	C	74.1	10.5	.	0	0	30	50	20	0	0	0	0	0	0	0
LQC	4	P	22.0	7.3	.	0	20	50	30	0	0	10	40	0	0	0	0
LQC	4	C	40.2	14.0	.	0	0	10	80	10	0	70	0	0	0	0	0
LQC	4	P	13.6	16.0	0.9	0	10	50	40	0	0	40	0	0	0	0	0
LQC	4	C	35.0	7.0	.	0	0	20	70	10	0	10	0	0	0	0	0
LQC	4	P	19.2	6.5	1.0	0	5	55	40	0	0	5	50	0	0	0	0
LQC	4	R	65.1	7.0	.	0	0	20	80	0	0	5	0	0	0	0	0
LQC	4	P	7.4	3.0	1.0	0	0	50	50	0	0	50	50	0	0	0	0
LQC	4	R	21.5	7.0	.	0	0	50	50	0	0	10	5	0	0	10	0
LQC	4	P	12.4	5.5	1.2	0	5	50	45	0	0	5	20	0	0	0	0
UQC	5	R	16.6	4.0	.	0	0	30	70	0	0	5	10	0	0	0	0
UQC	5	P	10.2	3.3	0.7	0	20	40	40	0	0	5	80	0	0	0	0
UQC	5	R	66.2	3.5	.	0	10	30	60	0	0	25	30	0	0	0	0
UQC	5	P	5.0	4.5	0.7	0	10	20	70	0	0	40	50	0	0	0	0
UQC	5	R	6.6	5.5	.	0	0	20	80	0	0	5	30	0	0	0	0
UQC	5	P	12.8	4.0	0.7	0	25	50	25	0	0	5	40	0	0	0	0
UQC	5	R	2.4	5.0	.	0	0	50	50	0	0	0	20	0	0	0	0
UQC	5	P	15.8	5.5	0.9	5	20	60	15	0	0	10	0	0	0	50	0
UQC	5	R	19.4	4.0	.	0	0	40	60	0	0	5	0	0	0	0	0
UQC	5	P	4.6	4.5	1.0	0	0	50	50	0	0	5	20	0	0	0	0
UQC	6	R	41.1	4.3	.	0	10	40	50	0	0	10	10	0	0	0	0
UQC	6	P	10.8	3.5	0.7	0	20	50	30	0	0	15	30	0	0	0	0
UQC	6	R	6.7	4.0	.	0	5	20	75	0	0	0	20	0	0	10	0
UQC	6	P	3.9	3.5	0.7	0	30	70	0	0	0	20	90	0	0	0	0
UQC	6	R	18.8	3.5	.	0	10	20	70	0	0	10	0	0	0	0	5
UQC	6	P	6.1	9.0	0.8	0	30	50	20	0	0	10	70	0	0	20	0

Appendix B continued.

						Substrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
UQC	6	R	9.3	3.5	.	0	30	70	0	0	0	10	25	0	0	0	0
UQC	7	P	4.9	5.3	0.7	30	30	40	0	0	0	10	50	0	0	15	0
UQC	7	C	21.4	2.5	.	0	0	20	80	0	0	10	0	0	0	30	0
UQC	7	P	6.0	5.0	0.9	0	0	50	50	0	0	30	30	0	0	0	0
UQC	7	R	8.9	2.5	.	0	0	20	80	0	0	10	0	0	0	0	0
UQC	7	P	4.6	4.0	0.8	0	10	70	20	0	0	40	0	0	0	10	0
UQC	7	R	17.6	3.0	.	0	0	50	50	0	0	5	50	0	0	50	0
UQC	7	P	4.7	3.5	0.8	0	20	40	40	0	0	25	0	0	0	0	0
UQC	7	R	61.0	2.0	.	0	0	50	50	0	0	0	0	0	0	25	10
UQC	7	P	6.1	3.0	0.9	0	20	60	20	0	0	10	80	0	0	0	0
UQC	7	P	9.3	3.5	0.6	0	20	60	20	0	0	5	0	0	0	0	0
UQC	7	C	17.2	3.7	.	0	0	20	80	0	0	30	0	0	0	0	0
UQC	7	P	7.8	4.0	0.8	0	45	45	10	0	0	5	100	0	0	0	0
UQC	7	R	20.4	3.0	.	0	0	30	70	0	0	5	50	0	0	0	0
UQC	7	P	5.3	3.5	0.8	0	30	60	10	0	0	25	80	0	0	0	0
UQC	7	R	46.5	3.5	.	0	0	40	60	0	0	30	0	0	0	0	0
UQC	7	P	3.4	2.0	0.8	0	30	70	0	0	0	5	40	0	0	0	0
UQC	7	R	5.5	3.0	.	0	5	65	30	0	0	0	10	0	0	0	0
UQC	7	P	11.4	3.5	0.8	0	10	50	40	0	0	10	0	0	0	0	0
UQC	7	R	72.6	.	.	0	5	30	65	0	0	5	0	0	0	0	0
UQC	8	P	6.2	4.2	0.6	0	10	40	50	0	0	5	0	0	0	0	0
UQC	8	C	10.8	4.0	.	0	0	30	60	10	0	0	0	0	0	0	0
UQC	8	P	11.3	5.0	0.9	0	0	40	60	0	0	10	0	0	0	0	0
UQC	8	R	15.5	5.5	.	0	0	20	60	20	0	0	0	0	0	0	0
UQC	8	P	4.6	4.0	0.6	0	5	35	60	0	0	5	0	0	0	0	0
UQC	8	C	77.9	.	.	0	0	20	40	40	0	5	0	0	0	0	0
UQC	8	P	6.6	5.0	0.6	0	0	20	60	20	0	5	0	0	0	0	0
UQC	8	C	12.3	3.5	.	0	0	20	40	40	0	0	0	0	0	0	0
UQC	8	P	4.8	4.5	1.3	0	0	20	40	40	0	0	10	10	0	0	0
RNB	9	SC	6.3	2.6	.	0	0	10	90	0	0	5	0	0	0	0	0
RNB	9	SP	2.9	2.5	0.6	0	0	70	30	0	0	15	0	0	0	0	0
RNB	9	SR	5.0	3.5	.	0	0	50	50	0	0	0	10	0	0	0	0

Appendix B continued.

						Substrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
RNB	9	C	9.6	4.0	.	0	0	10	80	0	0	5	0	0	0	0	0
RNB	9	P	12.1	5.0	0.7	0	25	35	35	5	0	10	5	5	0	0	0
RNB	9	C	64.9	4.0	.	0	0	10	70	20	0	10	0	5	0	0	0
RNB	9	SR	26.6	.	.	0	0	50	50	0	0	5	0	0	0	0	0
RNB	9	SP	6.6	.	0.4	0	25	65	10	0	0	30	25	0	0	0	0
RNB	9	SR	15.8	2.5	.	0	0	50	50	0	0	10	0	0	0	20	0
RNB	9	SP	1.9	2.5	0.3	0	20	50	30	0	0	20	0	0	0	0	0
RNB	9	SR	19.6	2.6	.	0	0	50	50	0	0	10	50	0	0	5	0
RNB	9	SP	5.7	1.5	0.6	0	10	50	40	0	0	5	50	0	0	50	0
RNB	9	SR	6.3	1.5	.	0	0	20	80	0	0	0	5	0	0	0	0
RNB	9	SP	4.8	2.5	0.4	0	10	60	30	0	0	25	0	0	0	0	0
RNB	9	SR	3.4	3.5	.	0	0	100	0	0	0	0	90	0	0	0	100
RNB	9	SP	5.4	2.5	0.5	10	10	40	40	0	0	5	0	0	0	0	70
RNB	9	SR	3.9	2.0	.	0	0	30	70	0	0	5	0	0	0	0	50
RNB	9	SP	31.6	3.0	0.6	10	50	20	20	0	0	20	50	0	0	0	20
RNB	9	SR	15.8	1.5	.	0	0	50	50	0	0	10	80	0	0	0	20
RNB	9	SP	4.6	2.0	0.3	0	30	60	10	0	0	0	50	0	0	0	20
RNB	9	SC	10.2	1.0	.	0	0	50	50	0	0	0	80	0	0	0	0
RNB	9	SP	4.2	2.0	0.6	70	30	0	0	0	0	40	0	0	0	0	0
RNB	9	SR	5.3	1.5	.	60	40	0	0	0	0	25	0	0	0	0	0
RNB	9	SP	4.1	2.0	0.5	30	30	40	0	0	0	50	0	0	0	0	0
RNB	9	SR	43.5	.	.	0	0	0	0	0	0	0	0	0	0	0	0
RNB	9	SR	11.5	2.5	.	0	0	30	70	0	0	5	0	0	0	0	0
RNB	9	SP	10.0	2.5	0.6	10	70	20	0	0	0	25	90	0	0	0	0
RNB	9	SP	6.5	2.0	0.5	0	10	80	10	0	0	10	50	0	0	50	0
RNB	9	LGJ	16.0	.	.	0	0	0	0	0	0	0	0	0	0	0	0
RNB	9	P	10.7	5.0	0.8	0	10	45	45	0	0	15	50	0	0	5	0
RNB	9	SP	16.5	2.5	0.9	0	0	0	0	0	0	5	100	0	0	50	0
RNB	9	SC	22.7	.	.	0	0	0	0	0	0	0	0	0	0	0	0
RNB	9	R	6.0	2.7	.	0	0	20	80	0	0	0	0	0	0	0	0
RNB	9	LGJ	10.6	.	.	0	0	0	0	0	0	0	0	0	0	0	0
RNB	10	R	42.2	8.0	.	0	0	60	40	0	0	0	0	0	0	20	0

Appendix B continued.

						Substrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
RNB	10	P	13.9	8.0	1.1	0	20	60	20	0	0	50	50	0	0	0	0
RNB	10	R	24.1	4.0	.	0	0	20	80	0	0	5	40	0	0	0	0
RNB	10	P	8.8	5.0	1.0	0	0	50	50	0	0	5	30	0	0	5	0
RNB	10	C	9.1	6.0	.	0	0	10	90	0	0	5	0	0	0	0	0
RNB	10	P	11.0	5.5	0.7	0	0	50	50	0	0	5	10	0	0	5	0
RNB	10	C	35.2	3.5	.	0	0	10	80	10	0	5	30	0	0	0	0
RNB	11	C	36.4	5.0	.	0	0	0	30	70	0	0	0	0	0	5	0
RNB	11	P	3.8	4.3	0.7	0	0	50	30	20	0	0	0	5	0	0	0
RNB	11	C	26.8	6.0	.	0	0	0	30	70	0	0	0	0	0	0	0
RNB	11	P	10.4	5.0	0.7	0	30	30	20	20	0	15	25	0	0	10	0
RNB	11	C	25.8	7.5	.	0	0	0	20	70	0	0	0	5	0	0	0
RNB	11	LGJ	9.3	.	.	0	0	0	0	0	0	0	0	0	0	0	0
RNB	11	C	30.8	7.0	.	0	0	40	30	30	0	5	30	5	0	0	0
RNB	11	P	9.9	5.0	0.7	0	0	30	40	30	0	0	50	10	0	5	0
RNB	11	C	3.6	5.5	.	0	0	0	50	50	0	0	50	0	0	5	0
RNB	11	P	4.2	4.0	0.8	0	20	20	50	10	0	0	50	10	0	0	0
RNB	11	C	5.0	4.5	.	0	0	0	30	70	0	0	0	0	0	0	0
RNB	11	P	7.1	6.6	0.9	0	0	40	40	20	0	15	40	0	0	0	0
RNB	11	C	13.0	6.0	.	0	0	0	30	70	0	0	40	5	0	0	0
RNB	11	P	7.3	5.0	0.7	0	0	30	60	10	0	5	0	0	0	0	0
RNB	11	C	22.1	7.5	.	0	0	0	40	60	0	5	0	5	0	0	0
RNB	11	P	9.8	5.0	0.8	0	0	0	30	70	0	0	0	15	0	0	0
RNB	11	C	73.8	5.5	.	0	0	0	20	80	0	5	0	10	0	0	0
RNB	11	P	6.5	5.0	0.7	0	5	25	35	35	0	0	0	15	0	5	0
RNB	11	C	22.0	6.5	.	0	0	10	20	70	0	5	0	10	0	0	0
RNB	11	P	3.6	6.5	0.7	0	5	25	35	35	0	0	0	5	0	0	0
RNB	11	C	39.2	6.5	.	0	0	10	40	50	0	5	0	10	0	0	0
RNB	11	P	7.0	6.7	0.7	0	5	35	30	30	0	5	30	5	0	0	0
RNB	11	C	28.6	6.0	.	0	0	10	20	70	0	0	0	5	0	0	0
RNB	11	P	10.9	3.5	1.2	0	5	5	30	60	0	25	0	10	0	0	0
RNB	11	C	22.5	8.0	.	0	0	10	50	40	0	10	0	5	0	0	0
RNB	11	P	12.9	5.5	0.8	0	0	25	35	40	0	5	0	10	0	0	0

Appendix B continued.

						Substrate type (Percent composition)						Cover type (Percent composition)					
Segment	Reach	Unit type	Length	Width	Pool depth	Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
RNB	11	C	6.3	4.0	.	0	0	0	40	60	0	10	0	5	0	0	0
RNB	11	P	9.2	5.0	0.7	0	5	25	40	40	0	0	0	10	0	0	0
RNB	11	C	76.0	6.5	.	0	0	0	30	70	0	0	0	15	0	0	0
RNB	11	P	10.6	4.5	0.8	0	5	10	35	50	0	0	0	10	0	0	0
RNB	11	C	7.8	3.5	.	0	0	0	30	70	0	0	0	5	0	0	0
RNB	11	P	4.2	5.5	0.8	0	0	10	20	70	0	0	0	10	0	0	0
RNB	11	C	11.3	3.5	.	0	0	0	20	80	0	10	0	0	0	0	0
RNB	11	P	5.6	2.5	0.7	0	0	30	50	20	0	15	40	5	0	5	0
RNB	11	C	8.8	6.5	.	0	0	0	50	50	0	0	20	5	0	0	0
RNB	11	P	5.4	8.0	0.7	0	5	25	30	30	0	5	0	20	0	0	0
RNB	11	C	30.6	6.0	.	0	0	0	20	80	0	0	10	10	0	0	0
RNB	11	P	5.4	4.5	0.8	0	5	10	35	50	0	0	0	20	0	0	0
RNB	11	C	39.2	8.0	.	0	0	20	50	30	0	5	0	10	0	0	0
RNB	11	P	5.3	6.5	0.6	0	15	35	25	25	0	0	0	20	0	0	0
RNB	11	C	10.1	7.0	.	0	0	10	40	50	0	5	0	5	0	0	0
RNB	11	P	14.8	5.9	0.8	0	5	10	45	40	0	20	0	25	0	0	0
RNB	11	C	34.5	5.5	.	0	0	0	30	70	0	5	0	0	0	0	0
RNB	11	P	3.5	5.5	0.9	0	0	20	20	60	0	0	0	10	0	0	0
RNB	11	C	12.8	7.0	.	0	0	20	20	60	0	0	0	15	0	0	0
RNB	11	P	3.6	7.0	0.6	0	0	30	30	40	0	0	0	10	0	0	0
RNB	11	P	7.5	7.5	0.8	0	5	10	45	40	0	0	0	15	0	0	0
RNB	11	P	8.6	5.5	0.7	0	0	10	30	60	0	0	0	20	0	0	0
RNB	11	C	27.2	6.0	.	0	0	0	10	80	0	0	0	10	0	0	0
RNB	11	P	4.4	5.0	0.8	0	0	10	60	30	0	0	0	20	0	0	0
RNB	11	C	29.2	6.5	.	0	0	0	20	80	0	0	0	10	0	0	0
RNB	11	P	10.2	7.3	0.7	0	0	30	30	40	0	5	0	5	0	0	0
RNB	11	C	3.7	6.0	.	0	0	0	10	90	0	0	0	0	0	0	0
RNB	11	P	8.0	5.5	0.9	0	0	0	40	60	0	0	0	10	0	0	0
RNB	11	P	6.6	5.5	0.8	0	0	5	35	60	0	5	0	15	0	0	0
RNB	11	C	32.7	7.0	.	0	0	0	40	60	0	5	0	10	0	0	0
RNB	11	P	7.4	7.0	0.8	0	5	10	30	65	0	0	0	15	0	0	0
RNB	11	C	17.1	8.0	.	0	0	10	20	70	0	0	0	15	0	0	0

Appendix B continued.

Segment	Reach	Unit type	Length	Width	Pool depth	Substrate type (Percent composition)						Cover type (Percent compostion)					
						Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
RNB	11	P	4.2	5.0	0.8	0	0	0	30	70	0	0	0	5	0	0	0
RNB	11	C	6.2	6.0	.	0	0	10	30	60	0	0	0	0	0	0	0
RNB	11	P	8.8	5.5	0.6	0	0	5	50	45	0	0	0	5	0	0	0
RNB	11	C	50.0	8.3	.	0	0	20	40	40	0	20	0	0	0	0	5
RNB	11	P	10.7	5.5	0.9	0	5	10	50	35	0	0	0	5	0	5	20
RNB	11	C	14.5	6.5	.	0	0	0	30	70	0	0	0	5	0	0	0
RNB	11	P	8.1	5.5	0.6	0	0	20	30	50	0	0	0	5	0	0	0
RNB	11	C	99.0	7.0	.	0	0	20	30	50	0	5	5	10	0	0	0
RNB	11	P	12.0	6.5	0.8	0	10	25	25	40	0	0	0	10	0	0	0
RNB	11	C	12.4	6.0	.	0	0	0	40	60	0	0	0	5	0	0	0
RNB	11	P	8.4	4.5	0.7	0	0	5	30	6.5	0	0	0	5	0	0	0
RNB	11	C	30.2	7.0	.	0	0	30	40	30	0	0	30	5	0	0	0
RNB	11	P	8.5	5.0	0.9	0	10	10	40	40	0	0	0	5	0	0	0
RNB	11	C	7.6	9.0	.	0	0	0	60	40	0	5	0	0	0	0	0
RNB	11	P	5.3	5.5	0.7	0	10	30	30	30	0	10	0	5	0	0	0
RNB	11	C	22.4	7.5	.	0	0	30	70	0	0	5	0	0	0	0	0
RNB	12	P	5.6	4.5	0.8	0	0	50	50	0	0	20	0	0	0	0	0
RNB	12	R	20.2	9.0	.	0	0	60	20	20	0	5	5	5	0	0	0
RNB	12	P	7.0	5.0	1.2	0	0	20	50	30	0	20	0	15	0	0	0
RNB	12	P	8.5	5.0	1.1	0	0	0	50	50	0	10	0	20	0	0	0
RNB	12	C	9.3	5.0	.	0	0	0	50	50	0	0	0	0	0	0	0
RNB	12	P	5.0	6.0	0.7	0	10	40	50	0	0	0	0	10	0	0	0
RNB	12	C	24.0	7.0	.	0	0	10	40	50	0	5	0	5	0	0	0
RNB	12	P	8.9	5.5	0.8	0	10	10	40	40	0	5	0	5	0	0	0
RNB	12	C	50.0	5.7	.	0	0	20	60	20	0	5	0	5	0	0	0
RNB	12	P	8.1	6.0	0.7	0	0	40	30	30	0	0	0	5	0	0	0
RNB	12	C	66.9	7.0	.	0	0	30	40	30	0	5	0	5	0	5	0
RNB	12	P	2.6	10.0	0.5	0	0	0	50	50	0	20	0	0	0	0	0
RNB	12	P	15.9	6.5	0.9	0	0	70	20	10	0	10	0	0	0	0	30
RNB	13	R	57.4	7.0	.	0	0	30	65	5	0	10	10	0	0	0	0
RNB	13	P	8.4	4.5	0.8	0	0	50	50	0	0	0	0	0	0	5	0
RNB	13	R	23.8	4.0	.	0	0	25	50	25	0	10	0	0	0	0	0

Appendix B continued.

Segment	Reach	Unit type	Length	Width	Pool depth	Substrate type (Percent composition)						Cover type (Percent composition)					
						Silt	Sand	Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	ALC	OHV	BKW
RNB	13	P	15.2	6.5	0.7	0	20	25	35	20	0	5	0	0	0	0	0
RNB	13	R	37.9	6.8	.	0	0	30	70	0	0	5	30	0	0	0	10
RNB	13	P	22.5	5.5	0.9	0	10	50	40	0	0	10	0	0	0	0	0
RNB	13	SP	12.6	4.0	0.7	10	10	80	0	0	0	10	0	0	0	0	0
RNB	13	SR	7.8	4.0	.	0	0	100	0	0	0	10	0	0	0	0	0
RNB	13	SP	22.4	3.5	0.7	0	20	60	20	0	0	5	20	0	0	0	0
RNB	13	SR	16.4	.	.	0	20	50	25	5	0	20	0	0	0	0	0
RNB	13	R	37.8	8.5	.	0	0	45	45	10	0	10	0	5	0	0	0
RNB	13	P	24.7	8.0	1.0	20	0	20	40	20	0	10	0	0	0	0	0

APPENDIX C

2008 BULL TROUT REDD COUNTS

Appendix C – Bull trout redd location in 2008 for Lower Quartz Creek (LQC), Upper Quartz Creek (UQC), and Rainbow Creek (RNB), tributaries to Quartz Lake, Glacier National Park, Montana.

Redd	Segment	Reach	Easting UTM	Northing UTM
R01	LQC	2	715703	5415091
R02	LQC	2	715710	5415097
R03	LQC	2	715627	5415056
R04	LQC	4	716127	5415507
R05	RNB	9	716146	5415511
R06	RNB	10	716211	5415646
R07	UQC	5	716235	5415540
R08	LQC	4	716041	5415303
R09	LQC	1	715435	5414718
R10	LQC	1	715513	5414888
R11	LQC	1	715500	5414881
R12	LQC	2	715686	5415082
R13	LQC	4	716036	5415471
R14	LQC	4	716057	5415487
R15	LQC	1	715455	5414742
R16	LQC	4	716059	5415329
R17	LQC	4	716054	5415447
R18	RNB	9	716150	5415511
R19	RNB	11	716193	5415777
R20	RNB	11	716245	5416215
R21	RNB	11	716290	5416605
R22	RNB	11	716291	5416696
R23	RNB	12	716261	5416913
R24	RNB	12	716277	5416959
R25	RNB	13	716221	5416970
R26	RNB	13	716160	5416992
R27	RNB	13	716145	5417002
R28	RNB	13	716144	5416999
R29	LQC	2	715686	5415071
R30	LQC	2	715740	5415172
R31	LQC	3	715767	5415200
R32	LQC	3	715774	5415233
R33	LQC	3	715810	5415247
R34	LQC	3	715819	5415256
R35	LQC	3	715821	5415258
R36	LQC	3	715830	5415264
R37	LQC	4	715992	5415269
R38	LQC	4	716023	5415297
R39	LQC	4	716039	5415299

Appendix C continued.

Redd	Segment	Reach	Easting UTM	Northing UTM
R40	LQC	4	716051	5415324
R41	LQC	4	716052	5415324
R42	LQC	4	716054	5415323
R43	LQC	4	716047	5415317
R44	LQC	4	716050	5415325
R45	LQC	4	716053	5415329
R46	LQC	4	716054	5415325
R47	LQC	4	716052	5415331
R48	LQC	4	716047	5415348
R49	LQC	4	716049	5415342
R50	LQC	4	716079	5415371
R51	LQC	4	716070	5415373
R52	LQC	4	716069	5415386
R53	LQC	4	716059	5415474
R54	LQC	4	716072	5415487
R55	LQC	4	716069	5415488
R56	LQC	4	716120	5415500
R57	LQC	4	716130	5415510
R58	UQC	5	716215	5415500
R59	RNB	10	716205	5415638
R60	LQC	1	715463	5414740
R61	LQC	1	715499	5414829
R62	LQC	1	715522	5414919
R63	LQC	1	715537	5414944
R64	LQC	1	715536	5414946
R65	LQC	2	715585	5415032
R66	LQC	2	715649	5415063
R67	LQC	2	715705	5415096
R68	LQC	2	715737	5415162
R69	LQC	3	715767	5415226
R70	RNB	10	716192	5415621
R71	LQC	2	715668	5415066
R72	LQC	2	715700	5415099
R73	LQC	2	715701	5415094
R74	LQC	3	715766	5415204
R75	LQC	3	715982	5415264
R76	LQC	4	716124	5415508
R77	LQC	3	715830	5415258
R78	LQC	4	715993	5415271
R79	RNB	9	716170	5415539
R80	RNB	11	716174	5415880

Appendix C continued.

Redd	Segment	Reach	Easting UTM	Northing UTM
R81	RNB	11	716238	5416086
R82	RNB	11	716305	5416340
R83	RNB	11	716302	5416414
R84	RNB	11	716297	5416514
R85	RNB	11	716235	5416780
R86	RNB	12	716274	5416928
R87	RNB	12	716273	5416942
R88	RNB	13	716277	5416972
R89	RNB	13	716263	5416980
R90	RNB	13	716259	5416995
R91	RNB	13	716163	5416985
R92	RNB	13	716159	5416995
R93	RNB	13	716149	5416995

APPENDIX D

2008 SUBADULT BULL TROUT SURVEYS

Appendix D – Subadult bull trout (BLT) electrofishing survey species counts and catch per unit effort (*C/f* ; number per minute) for each survey location in 2008 in Lower Quartz Creek (LQC), Upper Quartz Creek (UQC), and Rainbow Creek (RNB), tributaries to Quartz Lake, Glacier National Park, Montana. Efish unit = electrofishing unit number, S = slow water unit, F = fast water unit, WCT = westslope cutthroat trout.

Efish unit	Segment	Reach	Unit type	Easting UTM	Northing UTM	BLT count	BLT *C/f*	WCT count	WCT *C/f*
1	LQC	1	S	715461	5414756	4	0.22	2	0.11
2	LQC	1	F	715476	5414762	0	0.00	0	0.00
3	LQC	1	S	715491	5414794	1	0.25	0	0.00
4	LQC	1	F	715502	5414832	1	0.14	0	0.00
5	LQC	1	S	715510	5414872	2	0.33	0	0.00
6	LQC	1	S	715516	5414894	0	0.00	0	0.00
7	LQC	1	S	715553	5414982	0	0.00	0	0.00
8	LQC	1	F	715545	5414983	0	0.00	0	0.00
9	LQC	1	S	715524	5414940	0	0.00	0	0.00
10	LQC	1	F	715526	5414955	1	0.39	0	0.00
11	LQC	1	S	715510	5414842	0	0.00	0	0.00
12	LQC	1	S	715514	5414858	1	0.25	0	0.00
13	LQC	1	S	715560	5414992	0	0.00	1	0.24
14	LQC	1	S	715382	5414763	1	0.13	1	0.13
15	LQC	1	F	715448	5414761	1	0.54	0	0.00
16	LQC	1	S	715426	5414815	2	0.69	1	0.35
17	LQC	1	F	715438	5414827	0	0.00	0	0.00
18	LQC	1	S	715436	5414824	0	0.00	1	0.34
19	LQC	1	S	715464	5414879	3	0.60	1	0.20
20	LQC	1	S	715433	5414815	1	0.34	0	0.00
21	LQC	1	F	715458	5414851	0	0.00	0	0.00
22	LQC	1	F	715462	5414864	0	0.00	0	0.00
23	LQC	1	S	715483	5414851	0	0.00	0	0.00
24	LQC	1	S	715485	5414896	3	0.40	0	0.00
25	LQC	2	S	715581	5415018	3	0.23	0	0.00
26	LQC	2	F	715587	5415020	1	0.45	0	0.00
27	LQC	2	S	715608	5415048	3	0.24	0	0.00
28	LQC	2	F	715685	5415073	0	0.00	0	0.00
29	LQC	2	S	715710	5415111	3	0.38	2	0.25
30	LQC	2	S	715733	5415138	2	0.36	0	0.00
31	LQC	3	F	715769	5415219	0	0.00	0	0.00
32	LQC	3	S	715772	5415220	2	0.27	0	0.00
33	LQC	3	S	715797	5415246	0	0.00	0	0.00
34	LQC	3	F	715802	5415251	1	0.32	0	0.00
35	LQC	3	S	715860	5415234	2	0.53	0	0.00
36	LQC	3	S	715932	5415259	1	0.18	1	0.18

Appendix D continued.

Efish unit	Segment	Reach	Unit type	Easting UTM	Northing UTM	BLT count	BLT *C/f*	WCT count	WCT *C/f*
37	LQC	4	S	716049	5415431	1	0.17	5	0.87
38	LQC	4	F	716053	5415449	3	0.49	0	0.00
39	LQC	4	F	716099	5415497	1	0.34	3	1.01
40	LQC	4	S	716123	5415506	2	0.43	0	0.00
41	UQC	5	S	716235	5415525	0	0.00	0	0.00
42	UQC	5	S	716250	5415556	0	0.00	0	0.00
43	UQC	6	F	716254	5415594	0	0.00	0	0.00
44	UQC	7	F	716282	5415625	0	0.00	0	0.00
45	UQC	7	S	716302	5415637	0	0.00	0	0.00
46	UQC	7	S	716303	5415638	1	0.64	0	0.00
47	UQC	7	S	716402	5415730	0	0.00	0	0.00
48	UQC	7	S	716450	5415756	0	0.00	0	0.00
49	UQC	7	F	716459	5415758	0	0.00	0	0.00
50	UQC	8	F	716494	5415863	0	0.00	0	0.00
51	UQC	8	S	716546	5415942	0	0.00	1	0.28
52	UQC	8	S	716559	5415953	0	0.00	1	0.64
53	RNB	9	F	716095	5415510	0	0.00	0	0.00
54	RNB	9	S	716122	5415512	0	0.00	0	0.00
55	RNB	9	S	716117	5415527	0	0.00	0	0.00
56	RNB	9	F	716111	5415535	0	0.00	0	0.00
57	RNB	9	S	716160	5415579	0	0.00	0	0.00
58	RNB	9	S	716177	5415565	0	0.00	1	0.27
59	RNB	9	F	716189	5415585	0	0.00	0	0.00
60	RNB	10	F	716213	5415650	0	0.00	0	0.00
61	RNB	10	S	716222	5415674	0	0.00	0	0.00
62	RNB	10	S	716210	5415683	0	0.00	1	0.15
63	RNB	11	F	716188	5415856	0	0.00	0	0.00
64	RNB	11	S	716177	5415847	1	0.19	2	0.39
65	RNB	11	S	716172	5415879	0	0.00	1	0.27
66	RNB	11	F	716167	5415875	1	0.10	2	0.21
67	RNB	11	S	716213	5416077	0	0.00	0	0.00
68	RNB	11	S	716239	5416099	1	0.14	1	0.14
69	RNB	11	F	716249	5416115	1	0.05	2	0.10
70	RNB	11	F	716250	5416230	0	0.00	0	0.00
71	RNB	11	S	716250	5416228	0	0.00	1	0.32
72	RNB	11	S	716286	5416262	0	0.00	1	0.29
73	RNB	11	S	716324	5416393	1	0.31	4	1.25
74	RNB	11	S	716323	5416397	1	0.21	2	0.42
75	RNB	11	F	716312	5416431	1	0.14	3	0.41
76	RNB	11	S	716308	5416501	0	0.00	1	0.40

Appendix D continued.

Efish unit	Segment	Reach	Unit type	Easting UTM	Northing UTM	BLT count	BLT *C/f*	WCT count	WCT *C/f*
77	RNB	11	F	716307	5416504	1	0.15	8	1.23
78	RNB	11	S	716294	5416522	0	0.00	0	0.00
79	RNB	11	S	716274	5416718	0	0.00	2	0.83
80	RNB	11	S	716252	5416746	0	0.00	0	0.00
81	RNB	11	F	716249	5416754	0	0.00	2	0.69
82	RNB	12	F	716253	5416828	0	0.00	2	0.83
83	RNB	12	S	716250	5416831	0	0.00	0	0.00
84	RNB	12	S	716272	5416845	2	0.46	2	0.46
85	RNB	13	S	716182	5416965	0	0.00	8	1.21
86	RNB	13	S	716150	5417005	0	0.00	6	0.51
87	RNB	13	F	716161	5416993	0	0.00	0	0.00

APPENDIX E

2007 BULL TROUT REDD COUNTS

Appendix E – Bull trout redd location in 2007 for tributaries to Quartz Lake, Glacier National Park, Montana.

Redd	Easting UTM	Northing UTM
R01	715454	5414740
R02	715461	5414739
R03	715462	5414742
R04	715451	5414740
R05	715464	5414750
R06	715508	5414884
R07	715551	5414992
R08	715556	5414993
R09	715741	5415166
R10	716054	5415326
R11	716039	5415424
R12	716237	5415527
R13	716354	5415650
R14	715512	5414894
R15	715732	5415153
R16	716052	5415323

APPENDIX F

2007 SUBADULT BULL TROUT SURVEYS

Appendix F – Subadult bull trout (BLT) and westslope cutthroat trout (WCT) counts for each electrofishing location in 2007 in tributaries to Quartz Lake, Glacier National Park, Montana. Efish unit = electrofishing unit number.

Efish unit	Easting UTM	Northing UTM	BLT count	WCT count
1	715468	5414749	4	3
2	715501	5414833	4	0
3	715495	5414887	2	0
4	715535	5414931	5	1
5	715558	5414988	0	0
6	715600	5415072	1	1
7	715670	5415067	3	0
8	715665	5415081	0	0
9	715713	5415115	0	0
10	715767	5415209	2	0
11	715825	5415253	1	1
12	715879	5415241	2	1
13	716014	5415282	0	0
14	716046	5415384	1	1
15	710670	5415486	3	1
16	716134	5415501	1	0
17	716150	5415501	0	0
18	716188	5415563	0	0
19	716190	5415576	0	0
20	716188	5415593	0	0
21	716200	5415644	0	2
22	715376	5414785	1	0
23	715422	5414805	2	0
24	715455	5414848	2	0
25	715463	5414863	1	0
26	715469	5414887	2	0
27	715490	5414899	0	1
28	715507	5414933	1	0
29	715516	5414957	0	0
30	715347	5414827	2	0
31	715386	5414926	2	1
32	715441	5414833	0	0
33	715448	5414849	0	2
34	715452	5414866	1	0
35	715484	5414857	2	1
36	715481	5414837	1	0
37	715474	5414833	1	1
38	715525	5414880	1	0
39	715517	5414864	0	0

Appendix F continued.

Efish unit	Easting UTM	Northing UTM	BLT count	WCT count
40	715512	5414827	4	0
41	716210	5415686	0	1
42	716216	5415705	0	1
43	716190	5415781	0	7
44	716197	5415788	0	2
45	716195	5415860	0	0
46	716154	5415897	0	6
47	716160	5415906	0	1
48	716160	5415918	0	2
49	716181	5416025	0	4
50	716216	5416081	2	1
51	716246	5416106	0	2
52	716232	5416186	2	3
53	716285	5416260	1	6